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Editor

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THE LOOK BOX

World Oil Cartel

SEVERAL years back the President of the United States came home from his first conference with the British Prime Minister and spoke in high praise of the Atlantic Charter, which made plain its attitude of "equal access" to raw materials.

The Atlantic Charter never went before the United States Senate for consideration and in time most of the citizens of the United States came to look upon it as a collection of high-sounding phrases, without force and effect. In fact, the British Prime Minister issued some statements which were accepted as cutting the document into several parts.

Then in July, 1944, representatives of the two governments in Washington to consider collaboration in affairs of oil, and the references to the Atlantic Charter were sufficient in number to justify the suspicion that the Atlantic Charter is something more than an assortment of high-sounding phrases. At least it became the justification and the precedent for a conference, out of which came an agreement for setting up an International Petroleum Commission.

Now men in government as well as in the industry are classing this agreement as another assortment of high-sounding phrases, without force and effect. They raise the point that this agreement must go before the United States Senate, whose approval can give it force and effect. But the Atlantic Charter never had Senate blessing and it had sufficient force and effect to be used as justification for an agreement as to petroleum.

In the Atlantic Charter raw materials came in for an "equal access" attitude, which came to be accepted in many quarters as evidence that the two great powers were, to whatever extent the Atlantic Charter had force and effect, pledged to "free trade."

But the agreement as to a commission to direct the affairs of petroleum came to this grand purpose, so that:

"Adequate supplies of petroleum be available in international trade to the nationals of all peaceable countries at fair prices and on a non-discriminatory basis."

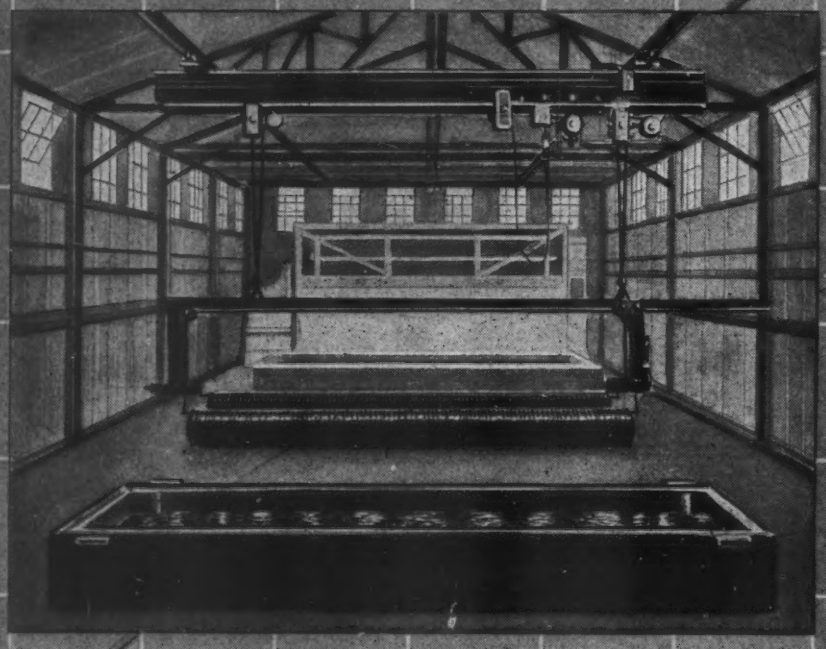
To whatever extent interpretations are accurate, it would seem that the "free trade" foundation has been used for a program whereby a commission will favor peaceful nations on a "non-discriminatory basis."

This agreement has been signed by Lord Beaverbrook for the British government and by E. R. Stettinius, Jr., Acting Secretary of State for the United States. Whether it ever goes to the United States Senate for ratification as a treaty or simply stands as a document of merit by its content is a question which the men and women of the petroleum industry should help to answer. Regardless of what course the agreement takes, it is going to have influence on the jobs and investments of the petroleum industry.

No commission can be successful in manipulating the affairs of international petroleum unless it has some authority over domestic petroleum affairs. Thus far all manner of meanings are being read into the agreement. Some are inclined to dismiss the document as without force and effect, simply because it is made up of high-sounding phrases. This attitude is not safe, as the influence of the Atlantic Charter indicates.

This International Petroleum Commission is

Dowtherm on the job!



Beating the fire hazard of asphalt at 390°F.!

Here is the interesting experience of a large culvert manufacturer in the use of the Dowtherm heat transfer method. Their problem involved the continuous, precise control of heat in a 20,000-gallon storage tank, and in two 6,000-gallon tanks used for the dipping of drainage pipe and culverts in asphalt at 390°F.

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charged with the responsibility of determining world markets and directing the distribution of oil accordingly. In order to accomplish this, it may come about that the total output of a nation, the United States as logically as any other, would have to be reduced. When and if this commission can bring that about, its action will have influence on the jobs and investments of those who make up the industry.

Reading meanings into the agreement goes on without hindrance, and here is one for consideration: It would make petroleum supplies available to nationals of "peaceable countries." Evidently this commission would be expected to determine the attitude of a nation as to war and peace and allot oil supplies accordingly. In such, oil would become the raw material for keeping the peace of the world. It could be provided on condition that a nation remain at peace.

It should be remembered that gasoline was shipped to Japan on somewhat the same basis in the months previous to Pearl Harbor. The petroleum industry has been condemned repeatedly for supplying gasoline to Japan. Few remember that those shipments went forward with the approval of the State Department.

Deceit under an International Petroleum Commission could be as successful and as deadly as it was under the watch of our State Department.

The petroleum agreement is in effect the machinery for a world-wide cartel in oil. It does seem peculiar that an administration which has been so persistent in its condemnation of private cartels would at the same time sponsor one whose effect can be as destructive as any of private building.

At Its Peak

EVEN the gangsters who manage the Third Reich must realize that it has but a few more days of existence. Its armies are being cut to shreds from two directions. Aerial opposition is negligible. Territory is surrendered without resistance. A self-styled super race has become a crowd of weaklings.

The situation in Europe is such that it safely can be accepted that consumption of petroleum in military channels is at its peak. It must continue for as long as Japan calls for attention but it is not comprehensible that the offensive against Japan ever can call for the outpouring of high-octane gasoline that was required to get an army on the Normandy coast and then release it from the shackles of the hedgerows.

What influence this will have on civilian supply and the conversion to peaceful pursuit hardly deserves speculation while there is need even for a lesser supply for the military. It is comforting to contemplate the fall of an Axis member with the assurance that petroleum has never been wanting for any military venture.

That status can be maintained as operations are accelerated in the Pacific. It is possible that the war in Europe will end before all facilities for making 100-octane aviation gasoline have been completed. Already the technologists have compounded an even more powerful motor fuel, which will make the super-bombers even more effective than its first raids indicated.

By Our Own Measure

SOMEHOW men can not resist the opportunity of justifying their shortages or shortcomings by pointing out that other nations are more severely ruled and more drastically rationed. Whether it is meat, shoes or gasoline the rationing authority in these United States adds up what has happened to the people of the United States, then cites the more severe situation abroad and asks—why should you complain?

The amount of any product available to the citizens of the United States should be determined by what is on hand and how much more can be provided. The fact that in England a family can have only a third of an egg a week is no criterion of what number or portion of eggs a family in this country should have.

The attitude should apply to gasoline or cigarettes. Suffering may be a consequence of winning a war but it is no contribution to victory.

War Plant Essential

AN essential in the disposition of war plants is being overlooked in the zeal that attends an affairs of the politician and the business man. The politician is determined that plants shall not fall into the ownership of "big" corporations or be used for price cutting or trust building.

The prime essential for the future of war plants is that they be put to work. If the equipment goes to work or continues at work, men will have work.

"There is a small but vocal minority in this country which seems to think we should make a gift of our assets to the less fortunate nations of the earth and level off our standards to those of other countries. As a nation we have always been sympathetic to less fortunate people and history shows that our country has ever been ready to help those in distress or in trouble. For us to hand over the results of our 170 years of struggle in the hope of making everyone in the world satisfied is impractical and unreasonable."

H. L. DERBY, *president, American Cyanamid & Chemical Company.*

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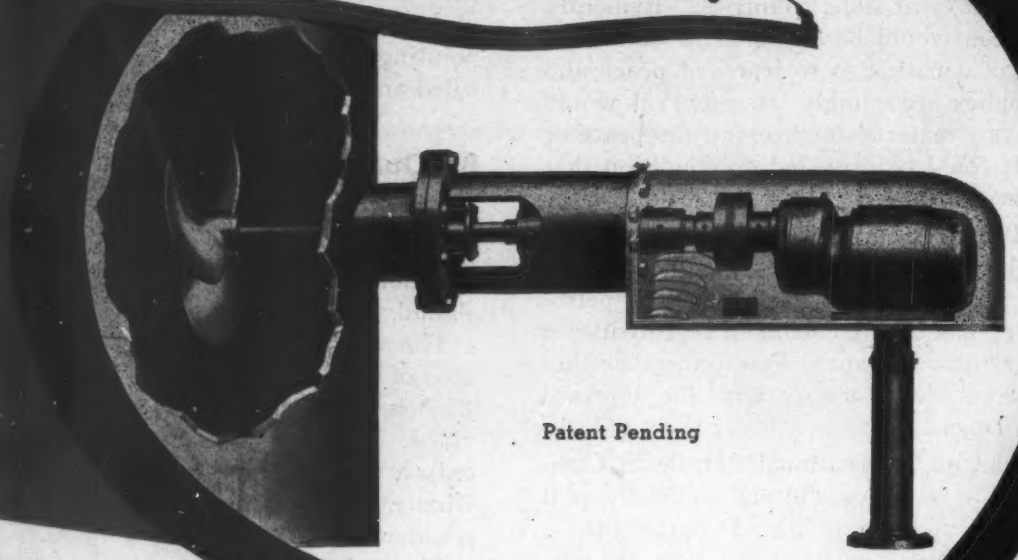

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Process Design Procedure for Multicomponent Fractionators

C. G. KIRKBRIDE
Professor of Chemical Engineering
Agricultural and Mechanical College of Texas
College Station, Texas

A RECOMMENDED process design procedure for multicomponent fractionators is presented. Two methods are given for the estimation of the number of theoretical trays required for a specified separation. A method for estimating tray efficiency to determine the actual number of trays to be installed is presented. Also a method is described for calculating the size tower required to handle the specified feed rate. An example design problem is solved which demonstrates the application of the recommended process design procedure.

The two methods for calculating the number of theoretical trays are the Brown, and the Brown and Martin methods. The Brown method was developed on a fundamental basis with a few simplifying assumptions. The Brown and Martin method is based on an empirical correlation. The Brown method is more fundamental and therefore more generally applicable than the Brown and Martin method. Nevertheless, the Brown and Martin method is more rapid and seems to be as reliable for multicomponent fractionator designs which involve the separation of hydrocarbons.

The method of Drickamer and Bradford is recommended for calculation of tray efficiency. The actual number of trays to be installed should be based on 85 percent of the efficiency predicted by their method. This provides for inaccuracies in the design methods and for flexibility in operation.

The recommended procedure for calculating the size tower to handle the specified feed rate is predicated upon fixing the tower diameter so liquid entrainment is negligible and then fixing the tray spacing to handle the liquid load.

Tower diameter is calculated on the basis of a maximum allowable vapor velocity. The maximum allowable vapor velocity is a function of the tower pressure, tower temperature and molecular weight of the vapor.

The tray spacing is calculated on the basis of the liquid back-up in the down-spouts. Liquid back-up in the down-spouts is due to the pressure drop through the trays and is equal to twice the depth of liquid on the tray plus the friction head of the vapor through the risers and caps plus the head required to induce the flow of liquid through the down-spout onto the tray below.

The methods for estimating the number of trays required are reliable within desired limits (± 10 percent); however, the methods available for estimating the capacity of a column are not as reliable as desired. It is believed that more effort should be directed toward improving the accuracy of the design methods for column capacity.

IT IS the purpose of this paper to present reliable process design methods for multicomponent fractionators. This includes two methods of estimating the number of trays required for a desired separation and a method of estimating the size of the column required to handle a desired capacity.

A great deal of attention has been devoted in the literature to methods of calculating the number of trays for a desired separation. This is important but it is of no greater importance than reliable methods of column design to assure the desired capacity. It is usually far more serious from the standpoint of operation to install a column with insufficient liquid capacity than to install one with an insufficient number of trays to attain a given separation at a specified reflux ratio. Operators who have had the bitter experience of trying to operate a column which floods (insufficient liquid capacity) at a point below the required capacity will appreciate fully the desirability of sufficient liquid capacity.

Actually a high degree of accuracy in the estimation of the required number of trays is not essential. It is relatively common practice to install 30 to 60 percent more trays than theoretical calculations indicate are required. Consequently a method for estimating the required number of trays at 100 percent tray efficiency, which is reliable within 10 percent, is well within required accuracy.

The methods of designing columns for given capacities are far short of this accuracy. The engineer is in general faced with the necessity of providing over 100 percent more column height than theoretical calculations indicate is required. It would appear, therefore, that the concentrated attention which has been devoted to improving the methods of estimating the number of theoretical trays might well be directed toward improving the methods of calculating the capacity of columns.

The following discussion takes up first the two methods of calculating the required number of trays. The first method, which was proposed by Brown and associates[1,3,4,5,6] is based on a theoretical approach with a few simplifying assumptions. The second method, developed by Brown and Martin[2] is empirical but seems to be essentially as reliable as the more fundamental method proposed earlier by Brown.[1] Next, the method of designing a column for specified capacity is presented. This covers a discussion of common difficulties in operation, estimation of tower diameter and tray spacing, and various reboiler installations. Finally an example design is presented

involves the application of the various recommended design methods.

Estimation of Required Number of Trays

Simplified Methods of Calculating Theoretical Trays.

Several methods have been proposed for calculating the number of trays required for a given separation of multicomponent mixtures. The method of Brown and co-workers[1, 3, 4, 5, 6] was one of the first simplified procedures to be presented which was based on a theoretical approach. Since then several such methods have been presented but they offer no significant advantages over the Brown method either from the standpoint of accuracy or rapidity. Brown and Martin,[2] however, presented a method which is more rapid than the Brown[1] method. It is based on an empirical correlation rather than a theoretical approach but the accuracy of the method seems to be essentially as great as that of the more theoretical Brown method.

The Brown[1] method was developed on the basis of constant rates of liquid down-flow and vapor up-flow in each section of the column namely, rectifying and stripping sections. Only the essentials of the method will be presented and discussed here. The development of the method can be found in the references given.

The Brown method employs the absorption factor and stripping factor concept. Equation (1) relates the absorption factor and separation with the number of theoretical trays required in the rectifying section (Figure 1). Equation (1) is presented graphically in Figure 2.

$$\frac{y_f - y_1}{y_f - K_1 x_o} = \frac{A^{n+1} - A}{A^{n+1} - 1} \qquad (1)$$

Where $A = L/VK_{av}$ = absorption factor
$K = y/x$ = equilibrium constant
L = average liquid down-flow above feed point, mols/hr.
n = number of theoretical trays above feed tray
V = average vapor up-flow above feed point, mols/hr.
x = mol fraction of a component in the liquid phase
y = mol fraction of a component in the vapor phase
Subscripts 1 = top tray of rectifying section
o = reflux drum
f = feed tray
av = average over rectifying section

Equation (2) relates the stripping factor and separation with the number of trays required in the stripping section (Figure 1). Equation (2) is presented graphically in Figure 2.

$$\frac{x_f - x_m}{x_f - y_{m+1}/K_m} = \frac{S^{m+1} - S}{S^{m+1} - 1} \qquad (2)$$

Where $K = y/x$ = equilibrium constant
$\overline{L}$ = average liquid down-flow in the stripping section, mols/hr.
m = number of theoretical trays below the feed tray
$S = K_{av}\overline{V}/\overline{L}$ = stripping factor
$\overline{V}$ = average vapor up-flow in stripping section, mols/hr.
x = mol fraction of a component in the liquid phase
y = mol fraction of a component in the vapor phase
Subscripts f = liquid from feed tray
m + 1 = vapor below the bottom tray of stripping section
m = bottom tray of stripping section
av = average over stripping section

In the design of a fractionating column the first step is to fix (1) the pressures on the reflux drum and on the column, (2) the compositions of the net overhead and bottoms, (3) the feed rate, (4) the feed temperature and (5) the reflux ratio. Theoretically it is possible to fix the concentration of only one component in the net overhead and the concentration of only one (another) component in the bottoms. Nevertheless, the usual design is predicated upon rather sharp separations between two key components* in which case the components boiling above the net overhead and the components boiling below the lower boiling key component are absent from the bottoms. At least this is sufficiently close to the true situation that it is an excellent initial assumption. After the number of trays has been established to give the specified separation between key components, it is a relatively simple matter to calculate the exact distribution of all other components between the overhead and bottoms by use of equations (1) and (2) or Figure 2.

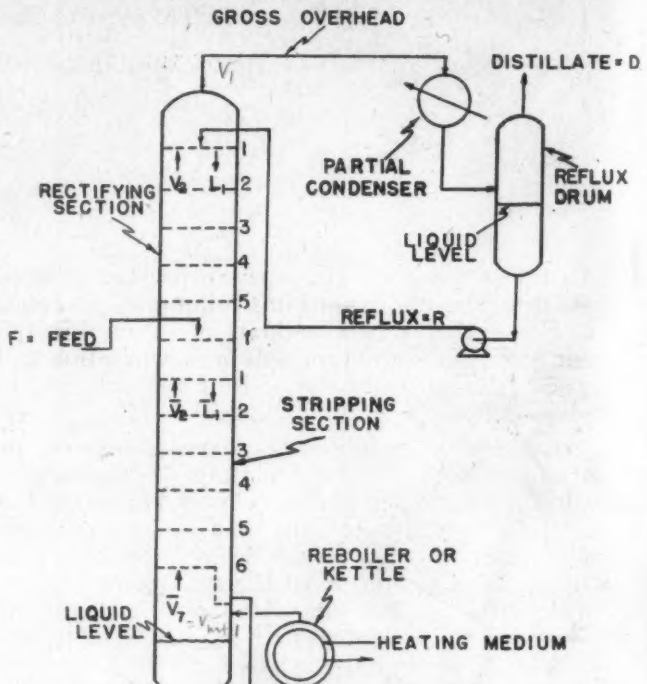

FIGURE 1
Schematic diagram of a multicomponent fractionater.

It is apparent from equations (1) and (2) that it is necessary to know the composition of the liquid and vapor leaving the feed tray in order to calculate the number of trays. This is perhaps the weakest point in the entire method and is certainly the most tedious. The composition of the feed-tray liquid and vapor can be calculated by use of equations (3), (4), (5), (6) and (7), each of which will be discussed below. The plan of attack involves a trial-and-error calculation. The feed-tray temperature is assumed. Then equation (3) is used to calculate the concentration in the liquid on the feed tray of each component which boils below the lower-boiling key component. Similarly equation (4) is used to calculate the concentration of each component in the liquid on the feed tray which boils above the higher-boiling key component. The concentrations of the components as calculated by equations (3) and (4) are then substituted into equations (5) and (6) in order to de-

*Key components are the two which are divided between the net-overhead and bottoms. Sometimes more than two components are divided between the net-overhead and bottoms. In this case the selection of the two key components will depend upon the distribution of each component.

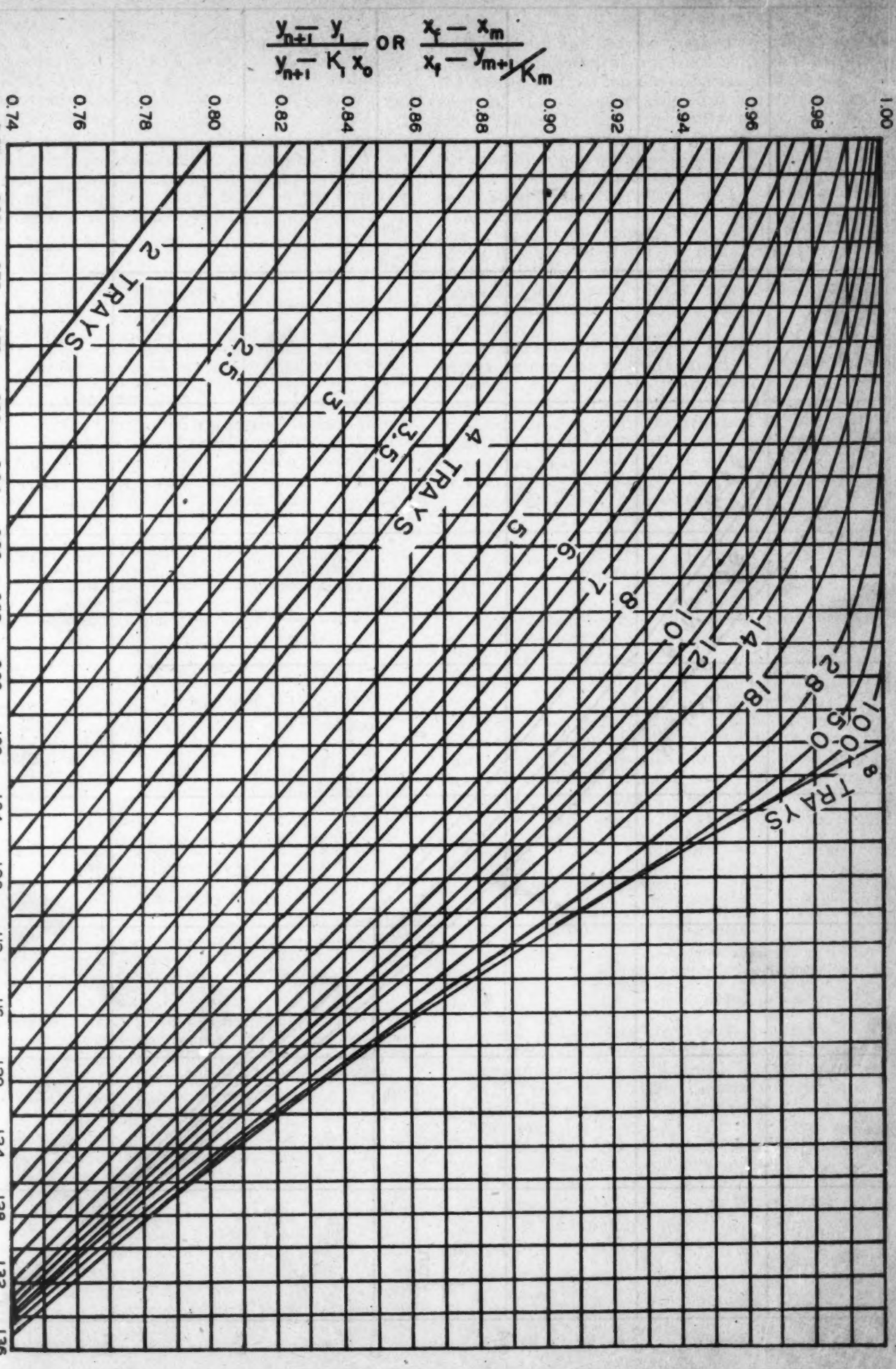
$\frac{y_{n+1} - y_1}{y_{n+1} - K_1 x_0}$ OR $\frac{x_f - x_m}{x_f - y_{m+1}/K_m}$
0.74
0.76
0.78
0.80
0.82
0.84
0.86
0.88
0.90
0.92
0.94
0.96
0.98
1.00
0.64
0.68
0.72
0.76
0.80
0.84
0.88
0.92
0.96
1.00
1.04
1.08
1.12
1.16
1.20
1.24
1.28
1.32
1.36
2 TRAYS
2.5
3
3.5
4 TRAYS
5
6
7
8
10
12
14
18
25
100
8 TRAYS
RECIPROCAL OF ABSORPTION OR STRIPPING FACTOR - $\frac{1}{A}$ OR $\frac{1}{S}$

FIGURE 2

$\frac{N}{N_{(r=1)}}$
$\frac{J}{J_{min.}}$
$N_{(r=1)} > 8$
$8 > N_{(r=1)} > 6$
$N_{(r=1)} < 6$
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

FIGURE 3

termine the concentrations of the two key components. If the correct feed-tray temperature was assumed equation (7) will be satisfied. Thus if the calculated composition does not satisfy equation (7) another feed-tray temperature must be assumed and the procedure repeated.

Equation (3) is based on a material balance around the rectifying section with the assumption that concentration of the components boiling below the lower-boiling key component is the same on the feed tray as on the tray above the feed tray.

$$x_f = \frac{D\,x_D/V}{K_f - L/V} \qquad (3)$$

Where D = net overhead, mols/hr.
K_f = equilibrium constant of a component at the feed tray temperature
L = liquid down-flow to the feed tray, mols/hr.
V = vapor up-flow to the tray above the feed, mols/hr.
x_D = mol fraction of a component in the net overhead
x_f = mol fraction of a component in the liquid on the feed tray.

Equation (4) is based on a material balance around the stripping section with the assumption that there is no change in concentration, between the feed tray and the tray below, of the components which boil below the higher-boiling key component.

$$x_f = \frac{W\,x_w/\overline{V}}{\overline{L}/\overline{V} - K_f} \qquad (4)$$

Where K_f = equilibrium constant of a component at the feed tray temperature
$\overline{L}$ = liquid down-flow from the feed tray, mol/hr.
$\overline{V}$ = vapor up-flow to the feed tray, mol/hr.
W = bottoms, mol/hr.
x_f = mol fraction of a component in the liquid on the feed tray
x_w = mol fraction of a component in the bottoms

Equations (5) and (6) are merely statements of definitions.

$$\Sigma x_f = 1.0 \qquad (5)$$

$$\Sigma y_f = \Sigma K_f x_f = 1.0 \qquad (6)$$

Equation (7) is called the Underwood[14] relation and is the check on the assumed feed-tray temperature

$$\frac{(L/D)\,x_{vf} + x_{vD}}{(L/D)\,x_{hf} + x_{hD}} < \frac{(L/D)\,x_{vF} + (\Delta/F)\,x_{vD}}{(L/D)\,x_{hF} + (\Delta/F)\,x_{hD}} < \frac{y_{vf}}{y_{hf}} \qquad (7)$$

Where $\Delta = \overline{L} - L$, mols/hr.
F = Feed rate, mols/hr.
Subscripts v = lower boiling key component
h = higher boiling key component
D = net overhead
f = feed tray
F = feed.

Occasionally it will be found that equation (7) is not satisfied at any assumed temperature of the feed tray. This indicates that the reflux ratio may be below the theoretical minimum for the desired separation. The equation can be satisfied by increasing the reflux ratio.

Brown[1] pointed out that the most accurate results are obtained with his method by making a tray-to-tray calculation down from the top tray of the rectifying section and up from the bottom tray of the stripping section until a constant temperature gradient is obtained. Then his method should be applied over the remainder of the rectifying and stripping sections. It has been found, however, that the improvement in accuracy does not justify the additional calculations. It is recommended therefore that the Brown method be applied over the entire rectifying and entire stripping sections.

Brown and Martin Method

The Brown and Martin[2] method for calculating the number of theoretical trays is less complicated than the Brown method but is not based on a fundamental approach. It is based on empirical correlations (equation 8). Even so it is apparently as accurate as the more fundamental Brown method.

Probably the greatest advantage of the Brown and Martin method is that it lends itself readily to the calculation of the most economical number of trays. The method has its limitations, however. It should not be used if the compositions of the feed and one of the products is nearly the same. Also the method is not reliable if the ratio of the number of trays obtained for the rectifying section to the number in the stripping section is less than 0.1 or greater than 10.

The method is based on a correlation of the ratio of the number of trays required, at a given reflux ratio, to the number of trays at infinite reflux ratio, with the vapor and liquid loads at the given conditions and at minimum reflux ratio. The correlation is given in Figure 3. It will be noted that the correlation provides for three different ranges of the number of trays at infinite reflux ratio, namely 8 to 6, greater than 8, and less than 6.

$$\frac{\frac{\overline{L}/\overline{V}}{L/V} - 1}{\left(\frac{\overline{L}/\overline{V}}{L/V}\right)_{min} - 1} = f\frac{N}{N_{(r=1)}} = \frac{J}{J_{min}} \qquad (8)$$

Where N = number of trays + reboiler + partial condenser
f = a function
$J = (\overline{L}/\overline{V}) / (L/V) - 1$
Subscripts min = at minimum reflux ratio
$(r = 1)$ = at infinite reflux ratio or $V/L = 1$.

In order to use the method it is necessary to calculate the minimum number of theoretical trays (infinite reflux ratio) and the theoretical minimum reflux ratio (infinite number of trays) which correspond to the desired separation. The minimum number of theoretical trays can be calculated by the Fenske[10] equation (9).

$$\left(\frac{x_v}{x_h}\right) = \left(\frac{x_v}{x_h}\right)_{si} \left(\frac{K_h}{K_v}\right)_{av}^{c+1} \qquad (9)$$

Where c = number of theoretical trays
Subscripts v = more volatile key component
h = less volatile key component
ai = top of section of rectifier
si = bottom of section of stripper.

It is best to calculate stepwise down from the top and up from the bottom until an essentially constant temperature gradient is obtained. Then equation (9) is applied over the sections of constant temperature gradient. The value of $N_{(r=1)}$ = stepwise trays at top and bottom + c + reboiler + partial condenser. In case a total condenser is used, no separation occurs in the reflux drum and nothing should be added for a partial condenser.

The stepwise calculation is simple because $V = L$ and $\overline{V} = \overline{L}$ at infinite reflux ratio. Starting with the partial condenser:

$y_0/K_0 = x_0 = y_1$
$y_1/K_1 = x_1 = y_2$
$y_2/K_2 = x_2 = y_3$.

Thus the stepwise calculation can be carried out from the partial condenser.

FIGURE 3

Starting from the reboiler or kettle:

$$y_{m+1} = x_m$$
$$(x_m)(K_m) = y_m = x_{m-1}$$
$$(x_{m-1})(K_{m-1}) = y_{m-1} = x_{m-2}.$$

Thus the stepwise calculation can be made from the kettle or reboiler. It is apparent that both stepwise calculations are quite simple.

The calculation of the minimum reflux ratio, on the other hand, is somewhat more complicated and tedious. The method proposed by Colburn[8] is the most reliable for estimating the minimum reflux ratio. It is of the trial-and-error type but even so it is not too time-consuming to make its use here undesirable.

The minimum reflux ratio is the lowest possible at which the desired separation can be attained with an infinite number of trays. Under such conditions the tray-to-tray concentration gradient of each component approaches zero in a region of each the stripping and rectifying section. This occurs due to the fact that the operating line and equilibrium curve approach each other closely and finally intersect.

Inasmuch as the composition of the liquid on the trays in the regions of zero concentration gradient is essentially identical, equations (3) and (4) are fundamentally sound for calculation of the composition. Nevertheless equations (10) and (11) as suggested by Colburn seem to involve less trial-and-error computations and are therefore recommended here.

Equation (10), which was presented by Gilliland[11] as a revision of an equation derived by Fenske[10] and Underwood,[14] is recommended for the calculation of the liquid composition in the region of zero concentration gradient in the rectifying section at minimum reflux ratio.

$$x_a = \frac{x_D}{(\alpha - 1)(L/D) + \alpha x_{hD}/x_{ha}} \qquad (10)$$

Where D = net overhead, mols/hr
L = liquid load in the rectifying section, mols/hr.
α = relative volatility of a given component with reference to the higher boiling key component
Subscripts a = region of zero concentration gradient in rectifying section
D = net overhead
h = higher boiling key component.

Equation (10) is used by assuming L and the temperature in the region of zero gradient. Since α does not vary much with temperature, the assumed temperature can be considerably in error without affecting the value of α significantly. The second term in the denominator can be disregarded in the first trial computation. The values of the concentration of each component boiling below the heavy key component can then be calculated. The value of x_{ha} is obtained as the difference between 1.0 and the sum of the concentrations calculated. Then a second trial calculation is made which includes the second term of the denominator with the value of x_{ha} just determined. This is repeated if necessary using the value of x_{ha} obtained in the second trial. The accuracy of the assumed temperature can be checked if desired by equilibrium balance using equation (6).

Equation (11) is similar to equation (10) but applies to the region of zero gradient in the stripping section at minimum reflux ratio.

$$x_s = \frac{\alpha_v x_w}{(\alpha_v - \alpha)(L/W) + \alpha x_{vw}/x_{vs}} \qquad (11)$$

Where L = liquid load in stripping section, mols/hr.
W = bottoms product, mols/hr.
α = relative volatility of a component with respect to higher boiling key component
α_v = relative volatility of lower boiling relative to higher boiling key components.
Subscripts s = region of zero concentration gradient in the stripping section
v = more volatile key component
w = bottoms product.

Equation (11) is used in a similar way to that of equation (10). The value of L and the temperature in the region of zero gradient are assumed and the concentration of each of the components boiling above the light key component is calculated. The concentration of the light key component, x_{vs} is obtained as the difference between 1.0 and the sum of the concentrations of the heavier components. In this case also the assumed temperature for obtaining α and α_v can be checked by equilibrium balance using equation (6).

The best procedure for the calculation of minimum reflux ratio is outlined briefly as follows:

1. Assume the liquid load in the rectifying section L and calculate its composition in the region of zero concentration gradient by use of equation (10).

2. By heat balance calculate the increase in liquid load due to the feed and add this to the liquid load in the rectifying section to obtain the liquid load in the stripping section. Then by equation (11) calculate the composition of the liquid in the region of zero gradient in the stripping section.

3. The assumed liquid rate in the rectifying section is then checked by equation (12).

$$\frac{x_{vs}x_{ha}}{x_{hs}x_{va}} = \frac{1}{(1 - \Sigma C_s \alpha x_s)(1 - \Sigma C_a x_a)} \qquad (12)$$

Where C = function in Figure 4.
α = ratio of K of a component to that of the higher boiling key component
α_v (in Figure 4) = K_v/K_h
Subscripts a = rectifying section, region of zero gradient
h = higher boiling key component
s = stripping section, region of zero gradient
v = more volatile key component.

The value $\Sigma C_s \alpha x_s$ is the summation of values of $C_s \alpha x_s$ for all components boiling above the higher-boiling key component. The value $\Sigma C_a x_a$ is a summation of values $C_a x_a$ for all components boiling below the most volatile key component.

4. If the value of the left member of equation (12) is less than that of the right member, the assumed value of L at the beginning of this procedure was too low. A higher value must be tried and the procedure repeated. The value of the left member of equation (12) changes rapidly relative to changes in the assumed value L, whereas the value of the right member changes only slightly. This simplifies the trial-and-error computations.

After the minimum number of trays and the minimum reflux ratio have been calculated, the number of theoretical trays is calculated by use of Figure 3. The ratio of the number of trays above the feed tray (including partial condenser) to the number below the feed tray (including the reboiler) can be calculated from equation (13).

$$\log (N_a/N_s) = 0.206 \log \left[\left(\frac{W}{D}\right)\left(\frac{x_{hF}}{x_{vF}}\right)\left(\frac{x_{vw}}{x_{hd}}\right)^2 \right] \qquad (13)$$

Where $N_a + N_s = N - 1$
Subscripts a = rectifying section
D = net overhead or distillate
F = feed
h = heavy key component
s = stripping section
w = bottoms product.

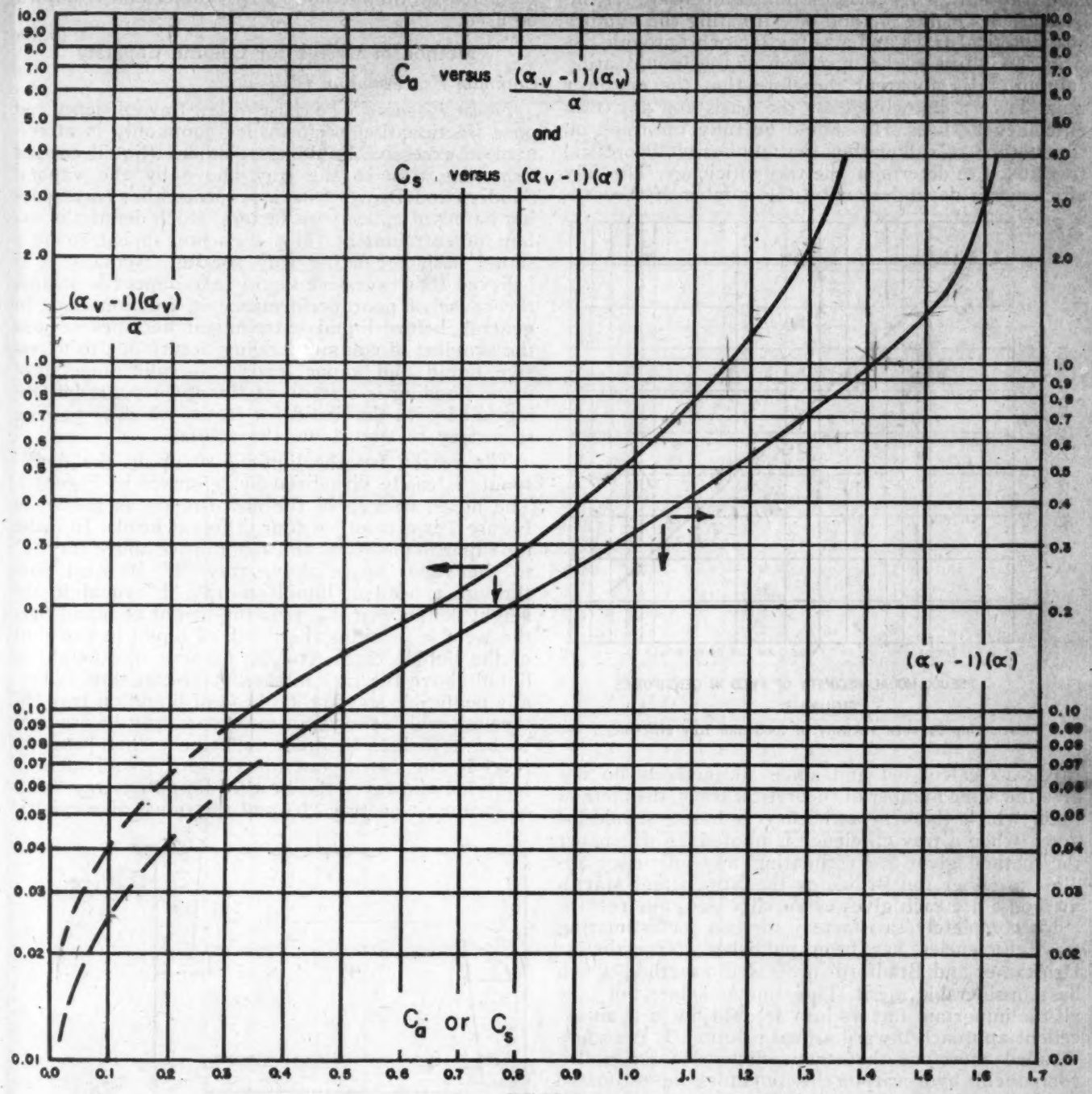

FIGURE 4

Function for use in Colburn method to determine minimum reflux ratio.

Equation (13) is preferred to the one suggested by Brown and Martin[2] since it correlates the data they gave on multicomponent fractionators as well as other data available to the author. It is empirical. It was developed on the basis that the ratio of rectifying trays to stripping trays (including partial condenser and reboiler) is a function of (1) the fraction of the heavy key component (in the feed) removed in the overhead, (2) the fraction of the light key component removed in the bottoms, (3) the concentration of the heavy key component in the overhead and (4) the concentration of the light key component in the bottoms. There are other variables which affect N_a/N_s but equation (13) seems to give reasonably good results.

Although the method for calculating the number of theoretical trays as described above is not exactly the same as presented by Brown and Martin,[2] the fundamental concept as described by them is identical. The use of the Colburn method for calculation of minimum reflux ratios and the use of equation (13) represent revisions in the procedure which it is felt improves the reliability and utility of the Brown and Martin correlation.

Estimation of Tray Efficiency.

The methods described above for calculation of the number of trays for a desired separation, give merely the theoretical number based on 100 percent tray efficiency. The actual number of trays required is ordinarily somewhat greater. The ratio of the number of theoretical trays to the actual number required multiplied by 100 is the tray efficiency. This should include not only a correction for inability to attain equilibrium between the liquid and vapor phases on

each tray but also a correction to compensate for the inaccuracies of the method of estimating the number of theoretical trays and a safety factor to provide desired flexibility in the operation of the fractionating column. It is apparent therefore that the engineer must have a knowledge of the basis for any tray efficiency he uses. He should be fully informed on the method of calculating the number of theoretical trays used to determine the tray efficiency. The tray efficiency is dependent upon the number of theoretical trays calculated and since all methods do not give the same number of theoretical trays, the method upon which the tray efficiency is based should be given when a tray efficiency is quoted. In this paper the method given for estimating tray efficiency applies to either the Brown or the Brown and Martin method since each gives essentially the same results.

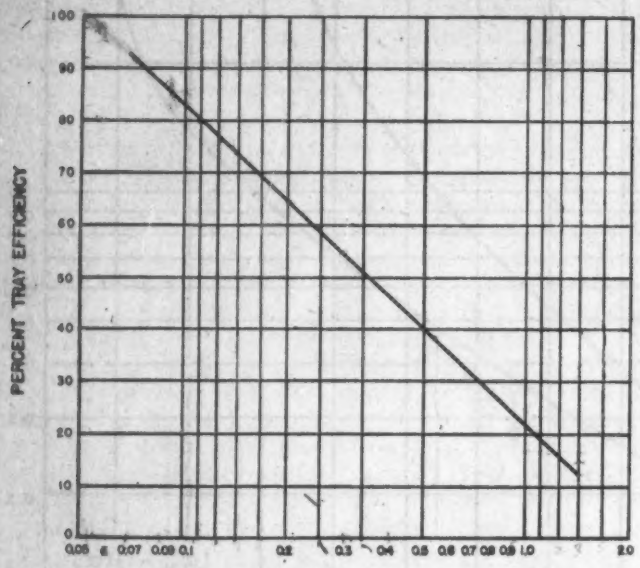

FIGURE 5

Relationship between viscosity of feed and tray efficiency.

No completely satisfactory method for estimating tray efficiencies has been published. Nevertheless Drickamer and Bradford[9] presented a method which has considerable merit. Their method does not take all the important factors into account but it is an excellent approach toward a final solution. It is recommended therefore that tray efficiencies for multicomponent hydrocarbon fractionators be estimated by their method, with additional allowance for flexibility and inaccuracies in the methods involved.

The method of Drickamer and Bradford is based on a correlation of pseudo molal viscosity of the feed at the arithmatic average tower temperature with overall tray efficiency. This is presented in Figure 5. The tray efficiencies used in their correlations were based in most cases on the Brown and Martin,[2] and the Brown[1] methods. The pseudo molal viscosity is the sum of the products of mol fraction and viscosity for each component in the feed. Viscosities of a number of paraffin hydrocarbons are given in Figure 6 to facilitate the calculation of pseudo molal viscosities.

The tray efficiencies calculated by the method described should be reduced 5 percent to compensate for inaccuracies in the methods. Also another 10 percent reduction ordinarily is advisable to provide desired flexibility in operation. Thus it is recommended that an overall tray efficiency of 85 percent of that predicted by the method of Drickamer and Bradford be used.

Method of Design for Column Capacity

Common Fractionation Difficulties.

Tower Flooding. The cause of low tray efficiency and poor fractionation performance commonly is attributed to excessive liquid entrainment (liquid carried from one tray to the tray above by the vapor). Souders and Brown[13] have proposed that tray spacing be based entirely on factors which define the extent of entrainment. This does not appear to be a sound basis for fixing tray spacing. Actually it is believed that excessive liquid entrainment is seldom the cause of poor performance in fractionation. In general, before liquid entrainment becomes serious the problem of column flooding occurs due to excessive liquid and vapor loads. The phenomenon of tower flooding is a result of the downspouts becoming filled with the liquid (or froth) which is passing from tray to tray down the column.

The reason for the liquid back-up in the downspouts is easily visualized by reference to Figure 7. The liquid backup in the downspouts as shown in Figure 7 is a result of four different heads. In order for vapor to pass from the vapor space above tray "a" to the vapor space above tray "b" it must pass through a head of liquid on tray "b" equal to the height of the weir, h_w, plus the height of liquid over the weir, h_{ow}, minus the depth of liquid in the slots of the bubble caps. At high capacity the height of liquid above the tray in the bubble-cap slots is usually negligible so the total head of liquid on tray "b" through which the vapor must pass may be assumed to be $h_w + h_{ow}$. In order to balance that head the level in the downspout must rise the equivalent of $h_w + h_{ow}$; however the head of liquid on tray "a" is the same as on tray "b" and this must also exist in the downspout from tray "b." Therefore for each unit head on a tray, two units of head must exist in the downspout or $2(h_w + h_{ow})$.

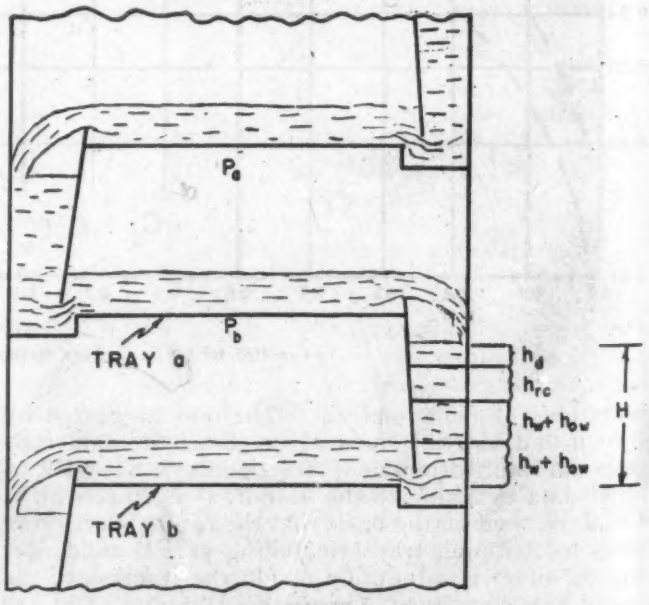

FIGURE 7

Cause of liquid back-up in downspouts.

The vapor passing through tray "b" also encounters a friction head through the riser and bubble-caps on tray "b." The equivalent head is designated as h_{rc}

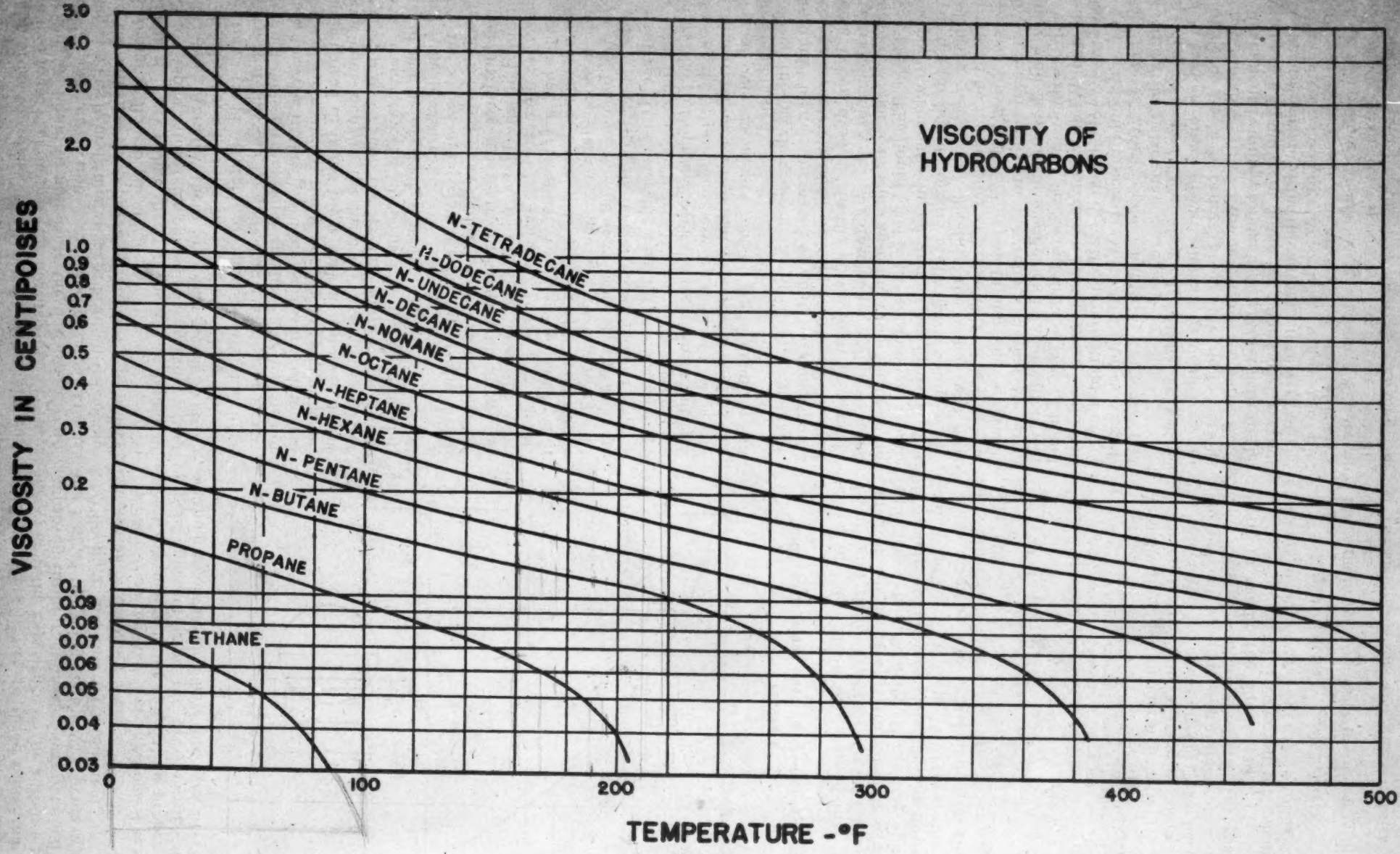

FIGURE 6

Viscosity of paraffin and olefin hydrocarbons.

NOTE—Olefins are approximately 15 percent more viscous than the corresponding paraffin hydrocarbon. Branched-chain hydrocarbons are approximately 10 percent less viscous than the corresponding normal hydrocarbon.

and in order to balance this head an equivalent head of liquid must back up into the downspout.

Then, for liquid to flow from the downspout onto tray "a" another friction drop is encountered. This is designated as h_d and an equivalent head must back up into the downspout to provide the energy to induce the required flow of liquid.

Thus it is seen that the total height of liquid in the downspouts must be equivalent to $2(h_w + h_{ow}) + h_{re} + h_d$. Actually there are other heads such as the head required to induce the flow of liquid across the tray. Good, Hutchinson and Rousseau[12] have shown that this can be quite important but a generally applicable method for estimating the head is not available. Also in the case of high-pressure columns in which the density of the vapor becomes significant, another head of liquid must back up into the downspout equivalent to the head of vapor between the level of tray "b" and the level of liquid in the downspout from tray "b." This usually is negligible but should not be overlooked in the case of columns at very high pressure.

In the above discussion the backup in the downspout is referred to as liquid. Unfortunately it is not liquid but instead is a froth. Considerable vapor is entrained in the liquid which flows over the weir. Therefore the actual head of froth in the downspouts is somewhat greater than would be necessary if it were all liquid. Once the vapor is entrained in the liquid entering the downspouts it passes down to the next tray because the linear velocity downward usually is greater than the velocity of bubbles rising to the surface. It is desirable therefore to design trays so that there is sufficient vapor disengaging area before the froth passes over the weir. Sufficient tray area should be provided between the last row of caps and the overflow weir so that a minimum disengaging time of one second per foot of liquid depth on the tray is obtained.

From the previous discussion it is apparent that if the liquid load is increased so that the downspouts become completely filled with liquid, the column will flood. When the head in the downspouts is equal to the tray spacing, the slightest increase in either the liquid or vapor load will cause the vapor space to fill with liquid. The liquid level in the column will rise to the point where the liquid and vapor loads do not over-tax the liquid capacity of the downspouts.

During periods of flooding the vapor which is produced by the reboiler or kettle will merely bubble upward through the column of liquid. The liquid will flow intermittently to the reboiler. That is, some liquid will flow to the reboiler and vaporization will occur. As this vapor passes upward the flow of liquid will stop. When vaporization ceases, more liquid will flow to the reboiler and so the intermittent flow of vapor and liquid proceeds. With this situation existing there is little wonder that tray efficiency and fractionation performance are poor.

Effect of Liquid Entrainment. It is believed that the most serious effect of entrainment is an increase in liquid load which brings about the more serious effect, flooding. After a tower reaches a flooded state, entrainment is quite pronounced. Entrainment to the extent of 0.4 pounds of liquid per pound of dry vapor has been determined by the author on towers at the beginning of flooding. According to Colburn[7] the effect of that much entrainment on tray efficiency (with no flooding) should be only about a 25 percent reduction based on liquid-to-vapor ratios usually employed. Actually the loss in tray efficiency in flooded towers is two to three times that value. In one case in the experience of the author a substantial improvement in fractionation was obtained by removing half of the trays. The tray spacing was doubled and flooding was thereby eliminated.

Estimation of Column Capacity.

Tower Diameter and Tray Spacing. The importance of reliable methods for calculating proper tray spacing is apparent from the previous discussion. The method recommended here involves first the calculation of the column diameter so that entrainment is nil and then the proper tray spacing is calculated on the basis of a tray design which provides sufficient liquid capacity. If the tray spacing should be found to be unreasonable, the tower diameter should be adjusted to permit reasonable spacing.

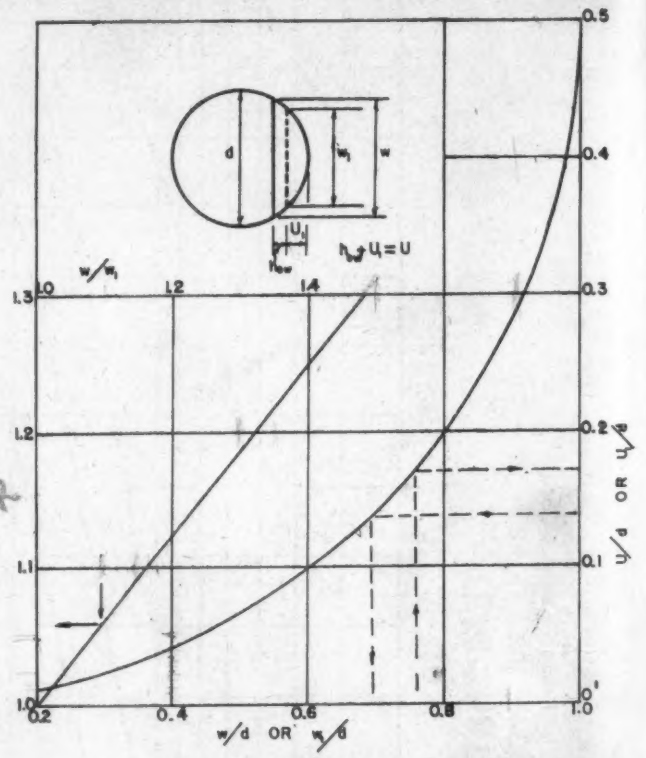

FIGURE 8
Correction to weir length for constricting tower wals.

The diameter can be calculated on the basis of a maximum allowable vapor velocity as given by equation (14).

$$v = 3.5\left(\frac{T}{MP}\right)^{1/2}$$

Where M = molecular weight of vapor
P = tower pressure (tbs/sq in)
T = temperature of vapor (°F/abs)
v = maximum allowable vapor velocity (ft/sec).

Actually there is considerable flexibility in fixing the diameter because the maximum allowable velocity as calculated by equation (14) can be exceeded by 100 percent without entrainment becoming important. This is true provided the tray spacing is adequate to handle the liquid load.

The recommended equation for calculating liquid backup in the downspouts is as follows:

$$H = 2(h_w + h_{ow}) + h_{re} + h_d \qquad (15)$$

The significance of this equation was discussed previously.

The height of the weir, h_w, is arbitrarily fixed but

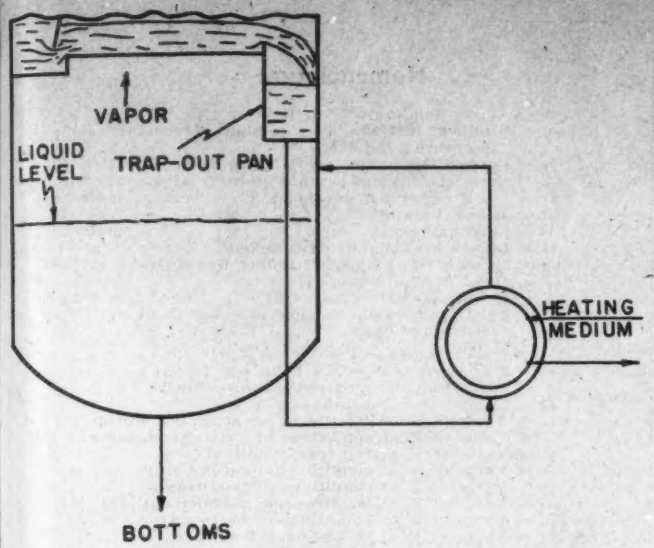

FIGURE 9
Complete trap-out reboiler installation.

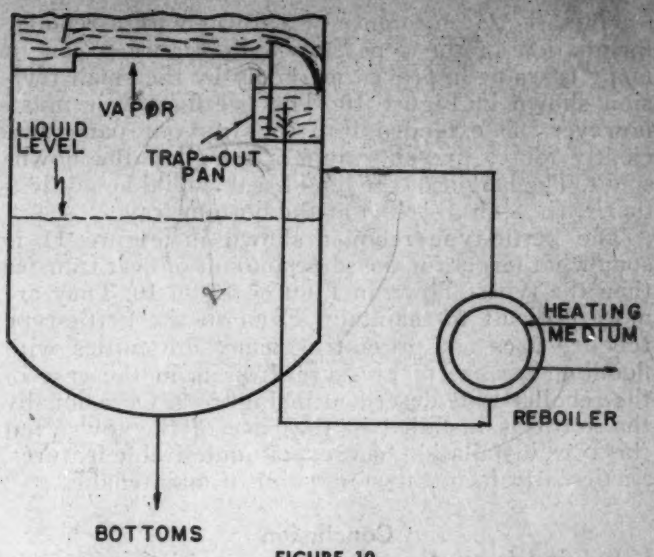

FIGURE 10
Non-flooding complete trap-out reboiler installation.

the term h_{ow} must be calculated. Equation (16) is recommended.

$$h_{ow} = 30k\left(\frac{L'}{W}\right)^{2/3} \qquad (16)$$

Where L' = liquid load, cu. ft./sec.
W = length of weir, inches
k = correction for constricting tower wall (Figure 8) when the weir is a chord of a circle. $k = 1.00$ in cases in which the tower wall does not constrict the flow.

It is apparent from equation (16) and (15) why entrainment is so serious from the standpoint of flooding.

The loss in head due to friction of the risers and caps can be calculated from equation (17).

$$h_{rc} = v_r^2\,(\rho_v/\rho_L) \qquad (17)$$

Where v_r = velocity through risers, ft./sec.
ρ_L = density of liquid, lbs./cu. ft.
ρ_v = density of vapor, lbs./cu. ft.

The head required to induce the flow of liquid through the downspouts can be calculated by equation (18).

$$h_d = 0.6\,v_d^2 \qquad (18)$$

Where v_d = maximum velocity of liquid through the downspouts, ft./sec.

The maximum velocity in the downspouts usually occurs at the bottom of the weirs in the downspouts (between the bottom of the weir and the overflow pan).

The method just described for calculating the backup in the downspouts is based on liquid being in the downspouts. Actually it is froth instead of liquid, so a correction must be applied. It is recommended that the tray spacing be not less than 200 percent of the liquid backup calculated by equations (15), (16), (17) and (18). With well designed trays the calculated liquid backup will reach 60 to 80 percent of the tray spacing before flooding is encountered. Now and then, however, difficulties with vapor entrainment in the liquid downflow will be experienced and flooding will occur at a calculated liquid backup of less than 60 percent of the tray spacing. More reliable information on vapor entrainment is needed to improve the design methods for column capacity.

Reboiler Installations. When difficulties with flooding occur at calculated liquid backups of less than 60 percent of tray spacing, the cause is frequently due to faulty reboiler installations. The liquid load in a column is usually highest at the bottom of the stripping section and unless the reboiler installation is properly designed to handle it, flooding may begin at the reboiler.

The installation shown in Figure 9 is particularly susceptible to this difficulty. In case the pressure drop through the reboiler is greater than anticipated the trap-out pan may fill with liquid and the lower part of the stripping section will flood. This will result in a substantial increase in entrainment and the higher liquid load may result in flooding of the entire stripping section. Even though the initial reboiler installation as described in Figure 9 may not have an excessive pressure drop, the deposition of solid material sometimes occurs, which results in excessive pressure drop and consequential flooding.

The potential difficulties of the installation in Figure 9 can be eliminated largely by the slight revision shown in Figure 10. The liquid from the bottom tray overflows into a trap-out pan which is installed so that the liquid which will not pass through the reboiler will overflow from the trap-out pan directly into the bottom of the tower. Any liquid which overflows in this way will undergo considerable vaporization due to coming in contact with the hotter liquid which passes through the reboiler. Thus with this type installation a part of the effect of one tray may be lost due to liquid overflow from the trap-out pan; however, the loss of all the trays in the stripping section will be avoided. The capacity and

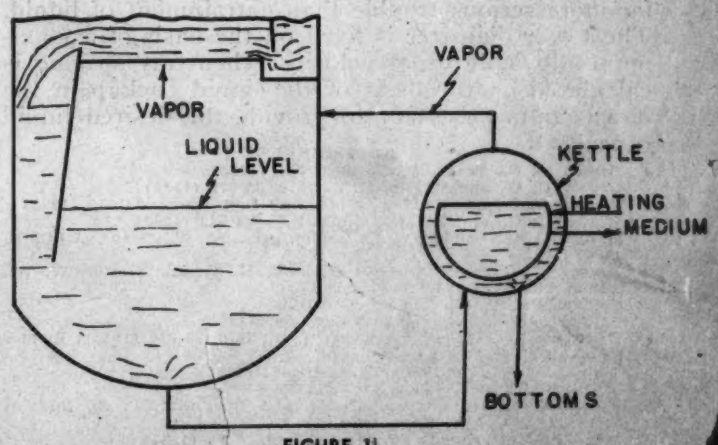

FIGURE 11
Kettle type reboiler instalation.

fractionation performance of a tower with a reboiler installation of the type shown in Figure 9 can in many cases be improved markedly by the small revision shown in Figure 10. The overflow weir must, however, be extended into the trap-out pan sufficiently far to prevent vapor passing up the downspout. The height of the liquid seal should be not less than 2 ($h_w + h_{ow} + h_{rc}$) at the bottom tray.

The kettle-type reboiler shown in Figure 11 is somewhat larger for the same amount of heat transfer than the types shown in Figures 9 and 10. They are more difficult to maintain. Even so the kettle-type reboiler does not present as many difficulties with flooding because of pressure drop as in the case of the reboiler type described in Figure 9. Occasionally the kettle is installed in the base of the tower but this type installation has several undesirable features, particularly from the standpoint of maintenance.

Conclusion

Judging from the preponderance of information in the literature on methods for calculating the number of theoretical trays required to make a given fractionation, it might be concluded that this is the problem of primary importance in the process design of fractionating columns. This is not so, however. More attention should be devoted to improving design methods for column capacity. Methods are available for calculating the number of theoretical trays which are reliable and reasonably rapid. Methods for estimating capacity are rapid but not so reliable as desired.

The Brown method for calculating the number of theoretical trays was developed on a fundamental approach and has the additional advantage of being reasonably simple. The Brown and Martin method is empirical but seems to be as reliable as the Brown method. It is somewhat the more rapid of the two. Upon extending the Brown and Martin method to new applications, it should be tested by a more fundamental method such as the Brown method, or by tray-to-tray calculations. After its reliability has been proven, it is the preferred method.

The method of Drickamer and Bradford seems to be the best available for estimating tray efficiency; however, allowance should be made for flexibility in operation and inaccuracy in the design methods. A tray efficiency of 85 percent of that predicted by the correlation of Drickamer and Bradford appears to be good practice.

The method of estimating tower capacity is rapid but a 100 percent safety factor must be applied to avoid difficulties with tower flooding. Flooding is a far more serious trouble than entrainment of liquid. The tower diameter is fixed on the basis of a maximum allowable vapor velocity. Then tray spacing is calculated on the basis of the liquid backup in the downspouts necessary to provide the desired liquid capacity.

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Nomenclature

A	= Absorption factor = L/K V	
c	= Number of trays over section of constant temperature gradient	
C_a	= Correlation value from Figure 4 for Equation 12	
C_s	= Correlation value from Figure 4 for Equation 12	
D	= Distillate or net overhead	mols/hr
d	= Tower Diameter	ft
F	= Feed rate	mols/hr
H	= Liquid back-up in down-spout	inches
h_d	= Head in down-spout to induce liquid flow	inches
h_{ow}	= Head of liquid over the weir	inches
h_w	= Height of weir above tray	inches
h_{rc}	= Friction head due to flow of vapor through risers and caps	inches
J	= $(\overline{L}/\overline{V})/(L/V) - 1$	
J_{min}	= J at minimum reflux ratio (∞ trays)	
k	= Correction for constricting tower wall	
K	= Equilibrium constant = y/x	
K_{av}	= Average K for rectifying or stripping section	
K_o	= Value of K at conditions of partial condenser	
K_1	= Value of K at top tray conditions	
K_2	= Value of K at conditions of second tray from top	
K_f	= Value of K at conditions of feed tray	
K_{m+1}	= Value of K at conditions of reboiler outlet	
K_m	= Value of K at conditions of bottom tray	
K_{m-1}	= Value of K at second tray from bottom	
K_h	= Value of K for heavy key component	
K_v	= Value of K for light key component	
L	= Liquid load in rectifying section	mols/hr
$\overline{L}$	= Liquid load in stripping section	mols/hr
L′	= Liquid load over weir	cu. ft./sec.
M	= Molecular weight of vapor	
m	= Number of trays in stripping section	
N	= Number of trays plus reboiler plus partial condenser	
N_a	= Number of trays above feed tray plus partial condenser	
N_s	= Number of trays below feed tray plus reboiler	
$N_{(r=1)}$	= N at infinate reflux ratio	
n	= Number of trays above feed tray	
P	= Pressure (abolute)	Lbs./sq. in.
R	= Reflux rate	mols/hr
S	= Stripping factor = $K_{av}\,\overline{V}/\overline{L}$	
T	= Temperature	°F. abs
U	= Distance from center of weir to tower wall	inches
U_1	= Distance from center of effective weir to tower wall	inches
V	= Vapor load in rectifying section	mols/hr
$\overline{V}$	= Vapor load in stripping section	mols/hr
v	= Maximum allowable vapor velocity in tower	ft./sec.
v_d	= Maximum liquid velocity in down-spout	ft./sec.
v_r	= Vapor velocity through risers	ft./sec.
W	= Bottoms product	mols/hr
w	= Weir length	inches
w_1	= Effective weir length	inches
x	= Mol fraction of a component in the liquid phase	
x_o	= x for reflux	
x_1	= x for liquid on top tray	
x_2	= x for liquid on second tray from top	
x_a	= x for liquid in region of zero concentration gradient in rectifying section	
x_D	= Mol fraction of a component in the net overhead	
x_f	= x for liquid on feed tray	
x_h	= x for heavy key component	
x_m	= x for liquid on bottom tray of column	
x_{m-1}	= x for liquid on second tray from bottom	
x_{m-2}	= x for liquid on third tray from bottom	
x_s	= x for liquid in region of zero concentration gradient in stripping section	
x_v	= x for more volatile key component	
x_w	= x for bottoms product	
x_{hD}	= x for heavier key component in distillate	
x_{hf}	= x for heavier key component in feed tray liquid	
x_{hF}	= x for heavier key component in feed	
x_{ha}	= x_a for heavier key component	
x_{hs}	= x_s for heavier key component	
x_{va}	= x_a for more volatile key component	
x_{vd}	= x_d for more volatile key component	
x_{vf}	= x_f for more volatile key component	
x_{vF}	= x_F for more volatile key component	
x_{vs}	= x_s for more volatile key component	
x_{vw}	= x_v for bottoms product	
$(x_v/x_h)_{at}$	= x_v/x_h at top of section of constant temperature gradient in rectifying section	
$(x_v/x_h)_{sl}$	= x_v/x_h at bottom of section of constant temperature gradient in stripping section	
y	= Mol fraction of a component in vapor phase	
y_o	= y of vapor from reflux drum	
y_1	= y of vapor from top tray	
y_2	= y of vapor from second tray from top	
y_3	= y of vapor from third tray from top	
y_f	= y for vapor from feed tray	
y_{m+1}	= y for vapor to bottom tray	
y_m	= y for vapor above bottom tray	
y_{m-1}	= y for vapor above second tray from bottom	
y_{vf}	= y_f for more volatile key component	
f	= a function	
α	= K/Kh	
α_v	= K_v/K_h	
Δ	= $\overline{L} - L$	mols/hr
Σ	= Summation symbol	
ρ_v	= Density of vapor	lbs./cu. ft.
ρ_L	= Density of liquid	lbs./cu. ft.

EXAMPLE OF SOLUTION

Example Design

Problem

A depropanizer is being designed to make the following separation:

	Mols./Hour		
	Feed	Net Overhead	Bottoms
Propane	54	51.8	2.2
n butane	377	2.7	374.3
n pentane	60	...	60.0
Total	491	54.5	436.5

The tower is to operate at 200 pounds per square inch, gauge, with a 5 pounds per square inch pressure drop to the reflux drum. The net overhead will be removed as gas from the reflux drum. A reflux ratio of 12 to 1 will be used. The feed is all liquid at 100° F. Calculate the number of trays, the tower diameter and the tray spacing to be installed.

Solution

Note: Equilibrium constants used are the MIT constants. Heat balances are based on enthalpy charts which were prepared from data in the literature on the individual hydrocarbons. Mol percentages are used in the calculations instead of mol fractions.

Plan of Solution:

1. Set up material and equilibrium balances
   a. Calculate temperatures of reflux drum, tower top and bottoms.
2. Make an overall heat balance.
   a. Determine reboiler duty.
3. Calculate liquid and vapor loads in column
   a. Vapor from reboiler
   b. Vapor to and liquid from the top tray.
4. Apply Brown's method for theoretical trays.
   a. Calculate feed tray composition
   b. Estimate the theoretical trays
   c. Calculate tray efficiency
   d. Estimate the actual trays to be installed.
5. Apply method of Brown and Martin for theoretical trays
   a. Estimate minimum theoretical trays
   b. Estimate minimum reflux ratio
   c. Estimate theoretical and actual trays.
6. Calculate tower size
   a. Calculate tower diameter
   b. Calculate tray spacing and tower height.

Calculations:

1. *Material and Equilibrium Balances*

	CHARGE			
	Mols./Hr.	Mol. %	Lbs./Hr.	Gals./Hr.
C_3	54	11.0	2,380	560
C_4	377	76.8	21,850	4490
C_5	60	12.2	4,320	820
	491	100.0	28,550	5870

	NET OVERHEAD			Assume Reflux Drum at 115° F.		
	Mols./Hr.	Mol. %	Lbs./Hr.	$K_{115°}^{210\ Lbs.}$	Mols./K	Mol. %
C_3	51.8	95.0	2,280	1.06	48.9	88.0
C_4	2.7	5.0	160	0.41	6.6	12.0
	54.5	100.0	2,440	....	55.5	100.0

Reflux drum at 115° F.

	BOTTOMS				Assume Vapor from Reboiler at 220° F.		
	Mols./Hr.	Lbs./Hr.	Mol. %	Gals./Hr.	$K_{220°}^{215\ Lbs.}$	(Mols.) (K)	Mol. %
C_3	2.2	100	0.5	20	2.25	5.0	1.1
C_4	374.3	21,690	85.7	4,450	1.07	400.0	91.7
C_5	60.0	4,320	13.8	820	0.52	31.2	7.2
	436.5	26,110	100.0	5,290	....	436.2	100.0

Bottoms at 220° F.

Using a cold reflux ratio of 12 to 1:

	REFLUX			GROSS OVERHEAD*		TOP TRAY		
	Mols./Hr.	Lbs./Hr.	Gals./Hr.	Mols./Hr.	Lbs./Hr.	$K_{127°\ F.}^{215\ Lbs.}$	Mol./K	Mol. %
C_3	575.5	25,300	5,910	627.3	27,580	1.17	536	75.5
C_4	78.5	4,600	945	81.2	4,760	0.47	173	24.5
Total	654.0	29,900	6,855	708.5	32,340	....	709	100.0

Top temperature = 127° F.
* $V_1 = R + D$

2. *Net Heat Balance*

		Btu./Lb.			
Net Overhead	Lbs./Hr.	Vapor 127°	Liquid 100°	ΔH	Btu./Hr.
C_3	2,280	184	38	146	330,000
C_4	160	190	34	156	20,000
	2,440	....	..	....	350,000
Reflux	**Lbs./Hr.**	**Vapor 127°**	**Liquid 115°**	**ΔH**	**Btu./Hr.**
C_3	25,300	184	48	136	3,440,000
C_4	4,600	190	42	148	680,000
	29,900	....	..	....	4,120,000
Bottoms	**Lbs./Hr.**	**Liquid 220°**	**Liquid 100°**	**ΔH**	**Btu./Hr.**
C_3	100	164	38	126	10,000
C_4	21,690	103	34	69	1,500,000
C_5	4,320	104	35	69	300,000
	26,110	....	..	....	1,810,000
Reboiler Duty— (by balance)	.....	....	..	....	6,280,000

3. *Liquid and vapor loads*

a. *Vapor from Reboiler (by heat and equilibrium balances around reboiler):*

Assume vapor of 896 mols./hr.

	VAPOR		Assume Liquid to Reboiler at 215° F.		
	Mols./Hr.*	Lbs./Hr.	Mols./Hr.**	$K_{215\ Lbs.}^{215°}$	(Mols.) (K)
C_3	9.9	440	12.1	2.21	26.8
C_4	821.6	47,600	1195.9	1.04	1242
C_5	64.5	4,650	124.5	0.50	62.3
	896.0	52,690	1332.5	....	1332.1

Reboiler inlet temperature = 215° F.
* Analysis calculated above.
** $\bar{L}_m = \bar{V}_{m+1} + W$

Reboiler Duty:

	Bottoms	Btu./Hr.			
	Lbs./Hr.	Liquid 220°	Liquid 215°	ΔH	Btu./Hr.
C_3	100	163	160	3	300
C_4	21,690	103	100	3	70,000
C_5	4,320	104	101	3	10,000
	26,110	....	....	....	80,300
	Vapors				
	Lbs./Hr.	**Vapor 220°**	**Liquid 215°**	**ΔH**	**Btu./Hr.**
C_3	440	333	160	73	32,000
C_4	47,600	217	100	117	5,565,000
C_5	4,650	227	101	126	586,000
.....	.....	....	....	....	6,183,000
					80,300
					6,263,300

This compares with 6,280,000 for perfect balance, which is close enough.

* SEE NEXT PAGE

EXAMPLE OF SOLUTION—Continued

b. *Liquid and vapor loads at top of column:*

Material Balance around top (See Figure 1):

$V_2 = L_2 + D$

Net Heat Balance around top:

$D(H_2 - H_1) + L_1(H_2 - h_1) = R(H_1 - h_0)$

Material Balance:

Assume $L_1 = 610$ mols/hr. and check by heat balance

	L_1			D		V_2	
	Mol. %	Mols./Hr.	Lbs./Hr.	Mols./Hr.	Lbs./Hr.	Mols./Hr.	Lbs./Hr.
C_3	75.5	460	20,250	51.8	2,280	511.8	22,530
C_4	24.5	150	8,700	2.7	160	152.7	8,860
	100.0	610	28,950	54.5	2,440	664.5	31,390

Equilibrium Balance on 2nd tray: Assume 135° F. and 140° F.

	V_2 Mols./Hr.	K 215 Lbs. 140°	Mols./K	K 215 Lbs. 135°	Mols./K
C_3	511.8	1.30	394	1.25	410
C_4	152.7	0.59	259	0.54	283
	664.5	....	653	....	693

Temperature of 2nd tray = 138°.

Heat Balance:

	D Lbs./Hr.	H_2	H_1	ΔH	Btu./Hr.
C_3	2,280	190	183	7	16,000
C_4	160	193	190	3	480
					16,480
	L_1 Lbs./Hr.	H_2	h_1	ΔH	Btu./Hr.
C_3	20,250	190	47	143	2,895,000
C_4	8,700	193	61	132	1,150,000
					4,045,000

Total heat in with D and L = 4,061,480
Total heat out with R = 4,120,000 (close enough)

4. *Brown's Method*

a. *Feed Plate Composition:*

Assume feed plate temperature = 195° F.

For C_3

$$x_f = \frac{W x_w / \overline{V}}{\overline{L}/\overline{V} - K_f} = \frac{60/896}{1332.5/896 - 0.41} = 6.2\%; \quad y_3 = 2.5\%$$

$x_4 + x_3 = 100.0 - 6.2 = 93.8$

$0.90x_4 + 1.93x_3 = 100.0 - 2.5 = 97.5$

$x_3 = 12.8; \quad y_3 = 24.7$

$x_4 = 81.0; \quad y_4 = 72.8$

Induced reflux above feed plate:

Assume heat per mol same as for liquid on feed plate.

Heat net overhead from 195° to 127°:

	Lbs./Hr.	Btu./Lb. Vapor 127°	Vapor 195°	ΔH	Btu./Hr.
C_3	2,280	184	220	−36	−80,000
C_4	160	190	205	−15	−2,400
	2,440	....	....	....	−82,400

Latent heat of induced reflux (based on feed plate analysis):

	Mols.	Lbs.	Btu./Lb. Vapor 195°	Liquid 195°	ΔH	Btu./106 Mols.
C_3	12.8	560	220	111	109	61,000
C_4	81.0	4700	205	87	118	555,000
C_5	6.2	450	219	89	130	58,500
	100.0	5710	....	....	....	674,500

Induced reflux $= \frac{4{,}120{,}000 - 82{,}400}{6{,}745} = 600$ mols/hr.

$= 34{,}200$ lbs./hr.

Vapor below feed plate:

Assume heat content same as for liquid on feed tray

Heat bottoms from 195° to 220°:

	Lbs./Hr.	Btu./Lb. Liquid 220°	Liquid 195°	ΔH	Btu./Hr.
C_3	100	163	111	52	5,200
C_4	21,690	103	87	16	350,000
C_5	4,320	104	89	15	60,000
	26,110	....	....	..	415,200

Vapor $= \frac{6{,}280{,}000 - 415{,}200}{6{,}745} = 870$ Mols/hr.

$\overline{V} = 49{,}700$ lbs./hr.

Correct feed tray analysis based on liquid and vapor loads at that point:

$\overline{L} = 870 + 436.5 = 1306.5$

$\overline{V} = 870$

For C_3; $x_f = \frac{60/870}{1306.5/870 - 0.41} = 6.3\%$; $y_3 = 2.6\%$

$x_4 + x_3 = 92.7$

$0.90x_4 + 1.93x_3 = 97.4$

$x_3 = 13.6; \quad y_3 = 26.2$

$x_4 = 80.1; \quad y_4 = 71.2$

Check analysis by equation (7):

$L/D = 600/54.5 = 11.0$

$$\frac{\overline{L} - L}{F} = \frac{870 + 436.5 - 600}{491} = \frac{706.5}{491} = 1.44$$

$$\frac{(L/D)x_{3f} + x_{3D}}{(L/D)x_{4f} + x_{4D}} = \frac{(11.0)(13.6) + 95.0}{(11.0)(81.0) + 5.0} = 0.273$$

$$\frac{(L/D)x_{3F} + \left(\frac{\overline{L} - L}{F}\right)x_{3D}}{(L/D)x_{4F} + \left(\frac{\overline{L} - L}{F}\right)x_{4D}} = \frac{(11.0)(11.0) + (1.44)(95.0)}{(11.0)(76.8) + (1.44)(5.0)} = 0.303$$

$Y_{3f}/Y_{4f} = 26.2/71.2 = 0.368$

Thus assumed feed plate temperature is correct

b. *Estimate of Theoretical Trays*

Trays for rectifying section:

$L/V = 600/654.5 = 0.919$ (above feed plate)

$L/V = 610/664.5 = 0.917$ (at top of column)

(L/V) av. $= 0.918$

For C_4; $K_{av} = \frac{0.47 + 0.90}{2} = 0.68$

Average $L/K_{av}V = 0.918/0.68 = 1.350$

$$\frac{y_f - y_1}{y_f - K_1 x_0} = \frac{71.2 - 11.5}{71.2 - (0.47)(12.0)} = 0.913$$

Theoretical trays are 4.4 by Figure 2

Trays for stripping section:

$\overline{L}/\overline{V}$ below feed $= 1306.5/870 = 1.5$

$\overline{L}/\overline{V}$ at bottom $= \frac{1332.5}{896} = 1.49$

Average $\overline{L}/\overline{V} = 1.495$

For C_3; $K_{av} = \frac{2.25 + 1.93}{2} = 2.09$

Average $\frac{K_{av}\overline{V}}{\overline{L}} = 1.40$

$x_m = \frac{(12.1)(100)}{1332.5} = 0.91$

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$$\frac{x_f - x_m}{x_f - \frac{y_{m+1}}{K_m}} = \frac{13.6 - 0.91}{13.6 - \frac{1.1}{2.21}} = 0.970$$

Theoretical plates = 7.0 by Figure 2

Theoretical Trays:

	Number
Rectifying section	4.4
Feed	1.0
Stripping section	7.0
Total	12.4

c. *Estimate of tray efficiency:*

Average tower temperature $= \frac{127 + 220}{2} = 174°$ F.

	Feed Mol. %	Viscosity at 174° F. Centipoises	(Vis.) (Mol. %)
C_3	11.0	0.057	0.627
C_4	76.8	0.120	9.200
C_5	12.2	0.150	1.830
	100.0	0.117	11.657

From Figure 5, efficiency = 74%
Use tray efficiency of (0.85) (74) = 63%

d. *Actual trays:*

	Number
Rectifying section	7.0
Feed trays	2.0
Stripping section	11.0
Total	20.0

5. *Method of Brown and Martin:*

a. *Minimum number of trays:*

Calculate down from top, tray to tray, until a constant temperature gradient is obtained:

	x_0	K_1 215 Lbs. 127°	x_1	K_2 215 Lbs. 140°	x_2
C_3	88.0	1.17	75.1	1.31	57.3
C_4	12.0	0.47	25.5	0.59	43.2
	100.0	....	100.6	....	100.5

$t_1 - t_0 = 12°$ and $t_2 - t_1 = 13°$ so O.K.

Calculte up from bottom until the plate to plate temperature gradient is constant:

	x_m	K_m 215 Lbs. 210°	x_{m-1}	K_{m-1} 215 Lbs. 205°	x_{m-2}
C_3	1.1	2.18	2.4	2.11	5.0
C_4	91.7	1.025	94.0	0.99	93.0
C_5	7.2	0.49	3.5	0.45	1.6
	100.0	....	99.9	....	99.6

$t_{m+1} - t_m = 215° - 210° = 5°$; $t_m - t_{m-1} = 5°$

$$\frac{x_{3s}}{x_{4s}} = \frac{5.00}{93.0} = 0.0538$$

$$\frac{x_{3a}}{x_{4a}} = \frac{57.3}{43.2} = 1.327$$

$$\left(\frac{K_4}{K_3}\right)_s = \frac{0.99}{2.11} = 0.47$$

$$\left(\frac{K_4}{K_3}\right)_a = \frac{0.59}{1.31} = 0.45$$

$$(x_{vs}/x_{hs})_{s1} = (x_{va}/x_{ha})_{s1}\left(\frac{K_h}{K_v}\right)_{sv}^{c+1}$$

$$0.0538 = 1.327\ (0.46)^{c+1}$$
$$c + 1 = 4.16$$
$$c = 3.16$$

Total trays = 2 + 3 + 3.16 = 8.16
$N_{(r+1)}$ = total trays + reboiler + partial condenser = 8.16 + 1 + 1 = 10.16

b. *Minimum reflux ratio:*

Assume temperature at zero gradient in rectifying section of 185° F.
Assume L = 200 mols/hr.
$\alpha_3 = 1.80/0.80 = 2.25$; L/D = 200/54.5 = 3.67
First trial:

$$x_{3a} = \frac{95.0}{(2.25 - 1)\ (3.67) + 0} = 20.7 \text{ mol\%}$$
$$x_{4a} = 100.0 - 20.7 = 79.3 \text{ mol\%}$$

Second trial

$$x_{3a} = \frac{95.0}{(2.25 - 1)\ (3.67) + (2.25)\ (5.0)/79.3} = 20.1 \text{ mol\%}$$
$$x_{4a} = 100.0 - 20.1 = 79.9 \text{ mol\%}$$

Liquid load in stripping section:

$$\bar{L} = L + fF$$

From previous calculations $fF = 1332.5 - 610 = 722.5$ mols/hr.

$$\bar{L} = 200 + 722.5 = 922.5 \text{ mols/hr.}$$

$$\bar{L}/W = 922.5/436.5 = 2.11$$

Assume temperature of region of zero gradient in stripping section = 190° F.
$\alpha_v = 1.88/0.86 = 2.19$
$\alpha_3 = 0.335/0.86 = 0.39$
First trial

$$x_{4a} = \frac{(2.19)\ (85.7)}{(2.19 - 1.00)\ (2.11) + 0} = 74.8 \text{ mol\%}$$

$$x_{5a} = \frac{(2.19)\ (13.8)}{(2.19 - 0.39)\ (2.11) + 0} = 8.0 \text{ mol\%}$$

x_{3a} = (by difference) 17.2 mol%

Second trial

$$x_{4a} = \frac{(2.19)\ (85.7)}{(2.19 - 1.00)\ (2.11) + (1.00)\ (0.5)/17.2} = 73.9 \text{ mol\%}$$

$$x_{5a} = \frac{(2.19)\ (13.8)}{(2.19 - 0.39)\ (2.11) + (0.39)\ (0.5)/17.2} = 7.9 \text{ mol\%}$$

$$x_{3a} = \text{(by difference)} = \frac{18.2 \text{ mol\%}}{100.0}$$

Check on assumed L_s by equation 12:

$x_{vs}/x_{hs} = 20.1/79.9 = 0.251$
$x_{va}/x_{ha} = 18.2/73.9 = 0.246$
$0.246/0.251 = 0.98$

$$\frac{(100)\ (100)}{(100 - \Sigma C_s \alpha x_s)\ (100 - \Sigma C_s x_s)} = \frac{x_{vs}\ x_{hs}}{x_{hs}\ x_{vs}} = 0.98$$

Since there are no components lighter than the light key component

$\Sigma C_s\ x_s = 0$
$(\alpha_v - 1)\ (\alpha) = (1.19)\ (0.39) = 0.465$
$C_s = 1.14$ (Figure 5)
$\Sigma C_s \alpha x_s = (1.14)\ (0.39)\ (7.9) = 3.5$

$$\frac{(100)\ (100)}{(100 - 3.5)\ (100)} = 1.037 \text{ which is greater than } 0.98$$

Thus the true value of L is slightly greater than 200 but this is close enough for the purpose.

c. *Estimate of trays:*

Applying Figure 3

$$\frac{\bar{L}/\bar{V}}{L/V} = \frac{1332.5/896}{610/664.5} = 1.62$$

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EXAMPLE OF SOLUTION—Continued

$$\left(\frac{\bar{L}/\bar{V}}{L/V}\right)_{min} = \frac{922.5/486.0}{200/254.5} = 2.42$$

$$\frac{1.62-1.00}{2.42-1.00} = \frac{0.62}{1.42} = 0.436$$

$N/N_{(n=1)} = 1.38$ from Figure 3
$N = (1.38)\ (10.16) = 14.0$

Theoretical trays exclusive of reboiler and reflux drum $= 14.0 - 2 = 12.0$ compared with 12.4 by the Brown method.

Ratio of trays above feed tray to trays below feed including partial condenser and reboiler:

$$\log (N_a/N_s) = 0.206 \log\left[\left(\frac{W\ x_{hF}}{D\ x_{vF}}\right)\left(\frac{x_{vw}}{x_{hD}}\right)^2\right]$$

$$= 0.206 \log\left[\left(\frac{436.5}{54.5}\right)\left(\frac{76.8}{11.0}\right)\left(\frac{0.5}{5.0}\right)^2\right]$$

$$= -0.052$$

$N_a/N_s = 0.888$
$N_a + N_s = N - 1 = 13$
$N_s = 13/1.888 = 6.9$
$N_a = 6.1$

Note: The equation, suggested by Brown and Martin for estimating the ratio of rectifying and stripping trays, gives $N_a = 4.9$ and $N_s = 8.1$ which is an improper distribution of trays between rectifying and stripping sections.

Theoretical trays:

	Number
Rectifying section	5.1
Feed tray	1.0
Stripping section	5.9
	12.0

Actual trays based on 63% efficiency:

	Number
Rectifying section	8.0
Feed trays	2.0
Stripping section	10.0
	20.0

Thus the agreement between the Brown and the Brown and Martin methods is good.

6. *Calculations on Tower Size*

a. *Tower diameter:*

Maximum vapor = 896 mols/hr.

$$= \frac{(896)\ (379)\ (15)\ (680)}{(3600)\ (215)\ (520)} = 8.6 \text{ cu. ft./sec.}$$

$$\text{Allowable velocity} = 3.5\left(\frac{T}{MP}\right)^{1/2} = 3.5\left(\frac{680}{(59)\ (215)}\right)^{1/2}$$

$$= 0.81 \text{ ft./sec.}$$

Cross section area = 10.6 sq. ft.
$d = [(1.275)\ (10.6)]^{1/2} = 3.67$ ft. — use 4.0 ft.

b. *Tray spacing*

Assume tray to be one pass having weir corresponding to chord of circle. Assume vapor riser area to be 12% of tower cross section area and weir length to be 80% of tower diameter.

1. Assume weir height of 1.5 inches

2. $h_{ow} = 30k\left(\frac{L'}{W}\right)^{2/3}$

Liquid from bottom tray:

	Mols./Hr.	Lbs./Hr.	Gals./Hr. at 60° F.
C_3	12.1	530	124
C_4	1195.9	69,300	14,220
C_5	124.5	8,970	1,710
	1332.5	78,800	16,054

Sp. gr. at 60° F. $= \frac{78,800}{(16,054)\ (8.33)} = 0.59$; Sp. gr. at 215° F. $= 0.475$

Volume at 215° F. $= \frac{(16,054)\ (.59)}{(.475)\ (3600)\ (7.48)} = 0.741$ cu. ft./sec.

$w = (48)(.80) = 38.4$ inches

$$h_{ow} = 30\ k\left(\frac{.741}{38.4}\right)^{2/3} = 2.16\ k$$

$w/d = 0.80$
From Figure 8, $U/d = 0.2$
$U = (0.2)\ (48) = 9.6$
Assuming $h_{ow} = 2.25$; $U_1 = 9.60 - 2.25 = 7.35$

$$\frac{U_1}{d} = \frac{7.35}{48} = 0.153$$

From Figure 8, $\frac{w_1}{d} = 0.72$

$$\frac{w}{w_1} = \frac{0.80}{0.72} = 1.11$$

$k = 1.07$
$h_{ow} = (1.07)\ (2.16) = 2.3$ inches (close enough)

3. $h_{rc} = v_r^2\left(\frac{\rho_v}{\rho_L}\right)$

Riser area $= (0.12)\ (16)\ (.785) = 1.51$ sq. ft.

$$v_r = \frac{8.6}{1.51} = 5.70 \text{ ft./sec.}$$

$$\rho_v = \frac{52,690}{(3,600)\ (8.6)} = 1.7 \text{ lbs./cu. ft.}$$

$$\rho_L = \frac{78,800}{(16,054)\left(\frac{.59}{.475}\right)} = 39.5 \text{ lbs./cu. ft.}$$

$$h_{rc} = (5.7)^2\frac{1.7}{39.5} = 1.4 \text{ inches}$$

4. $h_d = 0.6\ v_d^2$

Assume distance between end of downspout and bottom of overflow pan is 1.5 inches.

Minimum area $= (1.5)\ (38.4)/144 = 0.40$ sq. ft.

$$v_d = \frac{.741}{0.40} = 1.85 \text{ ft./sec.}$$

$h_d = (0.6)\ (1.85)^2 = 2.06''$

5. $H = 2(1.5 + 2.3) + 1.40 + 2.06 = 11.06''$

Tray spacing $= (11.06)\ (2) = 22.12''$, use $22.5''$

Allow $(1.5)\ (22.5) = 33.75$ or 34 inches of tower height above the top tray.

Allow 3 minute holding time at half full below bottom tray:

5290 gal/hr bottoms at 60° F.

$$(5290)\left(\frac{0.59}{0.47}\right) = 6640 \text{ gal/hr at } 215° \text{ F.}$$

$$= 14.75 \text{ cu ft/minute}$$

Volume of tower below bottom tray:
$(3)\ (2)\ (14.75) = 88.5$ cu. ft.
Height of tower below bottom tray:

$$\frac{88.5}{(0.785)\ (16)} = 7.05 \text{ or } 7 \text{ ft.}$$

$$\text{Tower height} = \frac{36 + 84 + 19(22.5)}{12}$$

$$= 45.6 \text{ ft.}$$

Install feed connections at the 7th, 9th, and 11th trays from the top.

A comfortable and well-equipped class room allowed instructors to bring their demonstrations into close observation

Three Hours of Training Improve Pump Efficiency At Baytown

AT BAYWAY refinery of Standard Oil Company of New Jersey there are well over 2000 steam and electric pumps performing productive operations, and constituting one of the chief maintenance problems. Each pump and each motor can fail in any one of a number of ways unless correctly operated, and each can waste power through inefficient operation; in aggregate this can mount to a substantial loss.

Under a program of preventive maintenance, all pump and motor operators are made highly conscious of these facts:

—that there is one correct method for starting, operating and stopping a unit, and that method is not only the most efficient but also the best preventive against breakdowns.

—that breakdowns can be greatly minimized not only in number but also in severity.

—that the operators' own eyes and ears are of the utmost importance in detecting potential failure or serious trouble.

At Bayway, the preventive maintenance program was keyed to a training course which was given to

A demonstration of the proper method for starting a steam duplex pump

top supervisors on down to pump and motor operators. While the effect of such a program, which, of necessity must center around the training course, cannot be fully measured, the following comparisons of specific breakdowns at the refinery over two winter-month periods indicate in part the program's value:

	Before Program Nov. 1942 to April, 1943	After Program Nov. 1943 to April, 1944
Cracked steam cylinders due to freeze-up	25	8
Cracked liquid ends due to freeze-up	12	6
Burned-out motors due to improper starting	20	6
Bearing failures due to improper care of lubricant, spraying cooling water into bearing, etc	130	60

The training course itself was devised and conducted by six instructors from process and mechanical departments who had previously been given the War Manpower Commission's 20-hour Instructor Institute Course. These men worked out a course aimed to meet specific problems in their own refinery.

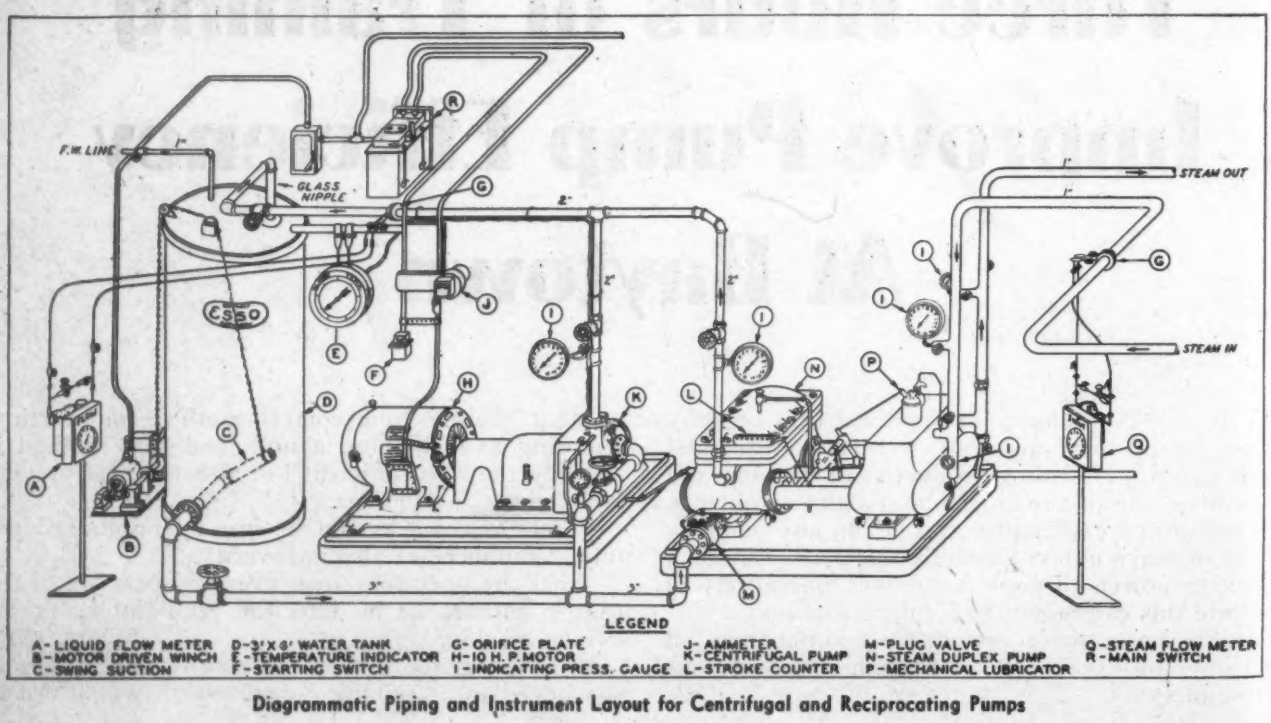
Necessary equipment was installed in a room 22-40 feet, arranged as shown in Figure 1. Large gauges, meters and indicators were selected and so placed as to be easily seen by members of the group. A large clock was equipped with a second hand, which could be used in timing the steam pump.

Operating the equipment involved taking suction from the 3x6-foot tank, filled with fresh water and colored with red, and discharging with either pump through the overhead connection back into the tank. The tank was made from a salvaged section of stack. Orifice flow meters of the large face indicating type were connected to the live steam supply and to the liquid discharge pipe. Orifice sizes were adjusted to give readings in even hundreds of pounds of steam per hour and even thousands of gallons of liquid flow per hour. A glass nipple provided a view of the liquid returning to the tank. The tank was covered to support the swing suction pulleys and to prevent splashing which occurs particularly when demonstrating loss of suction.

A motor-driven winch, operating on a 25-to-1 ratio, was connected to the internal swing suction and used to demonstrate the effects of loss of suction. Bleeder valves, drips, electrical starting equipment followed standard installation practice. One plug was incorporated in the design so its correct operating procedure could be demonstrated.

The duplex steam pump was connected to outport exhaust since no exhaust main was convenient. It was equipped with a stroke counter to assist in demonstrating over-speed and proper speed as described in the text.

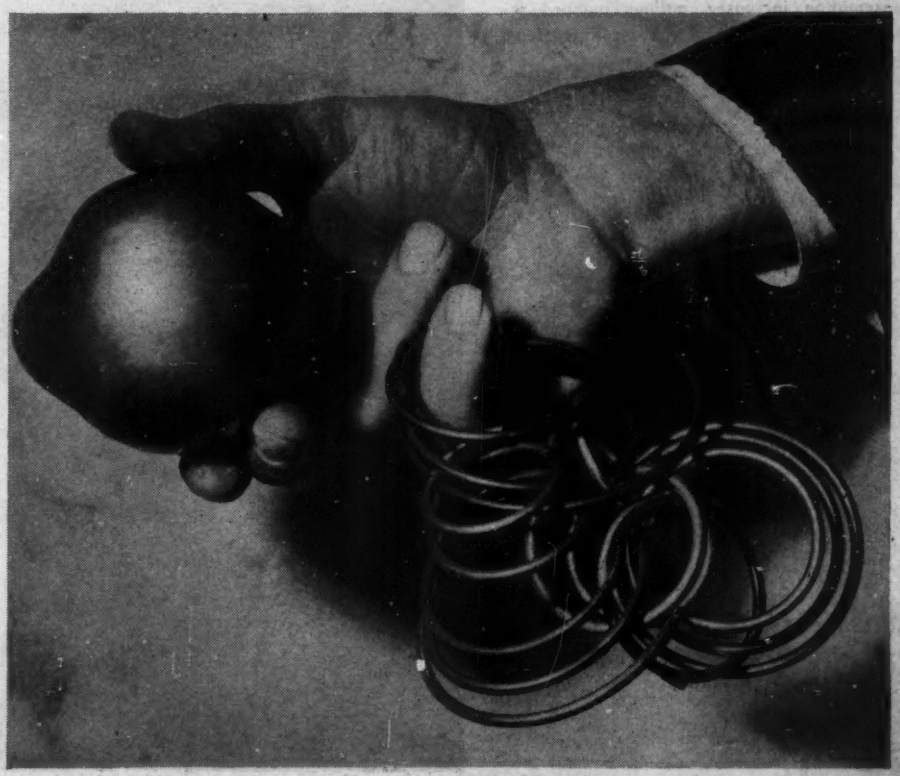
The motor-driven centrifugal pump, pedestal type, was connected to a 10-horsepower, explosion-proof motor, rated to deliver 60 gallons per minute at 75-



Diagrammatic Piping and Instrument Layout for Centrifugal and Reciprocating Pumps

Louis H. Zepfler, steam and power engineer, points to the result when drain valves are not opened. The cracked cylinder came from freezing water.

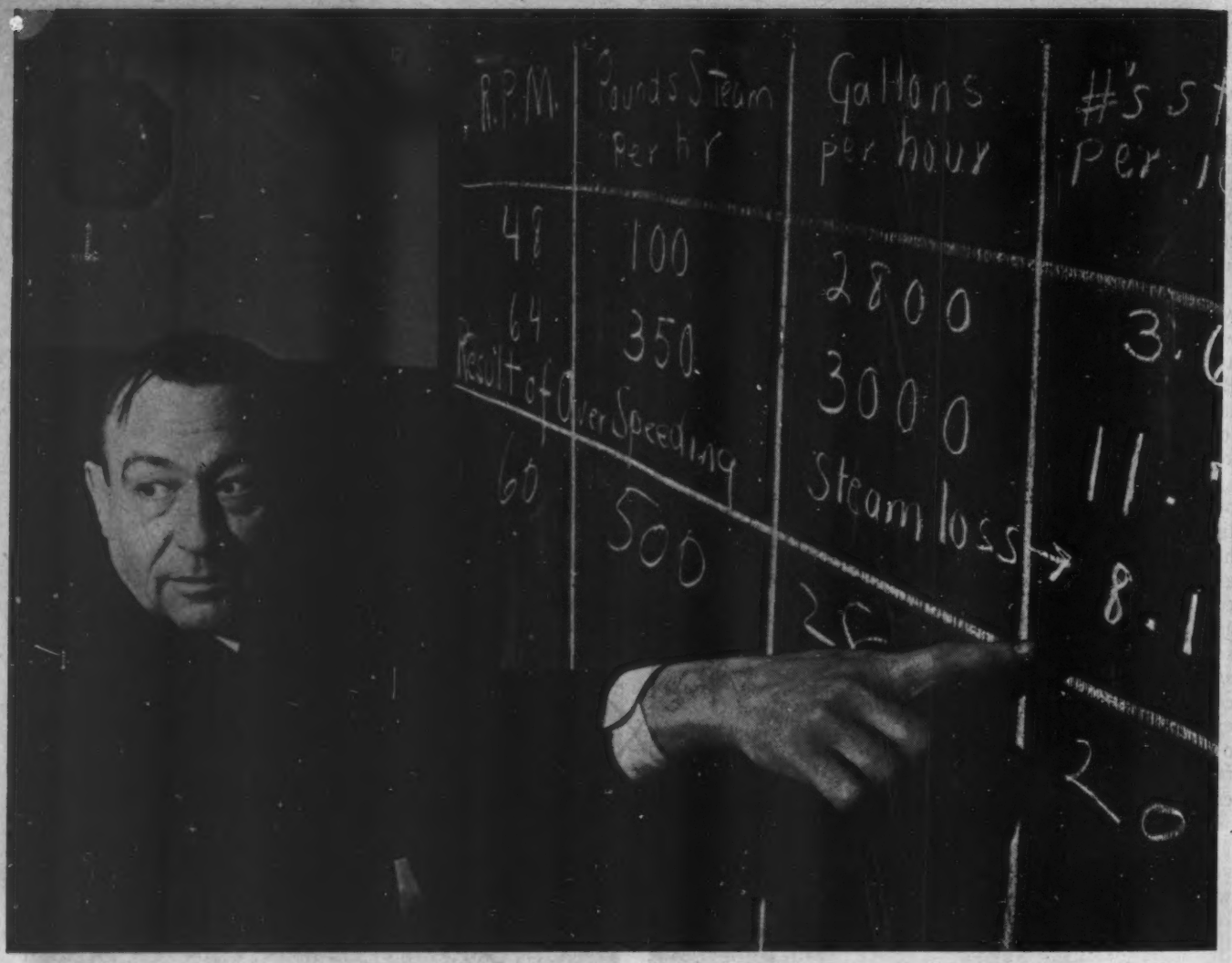
Improper operation of plug valves is shown by a new plug left and one, right, damaged by throttling and improper lubrication.



Much of the teaching at Bayway was by visible approach. Men who daily operate equipment sat down and watched the consequence of improper operation.

Damaged parts were brought out for inspection and the reason for the damage was evident.

At the right are the broken springs and distorted ball valve from a pump, which had operated at too high speed.



Above is the score on overspeeding a steam duplex pump. Strokes per minute go up, steam consumption increases, gallons pumped increases but slightly and the result is steam loss.

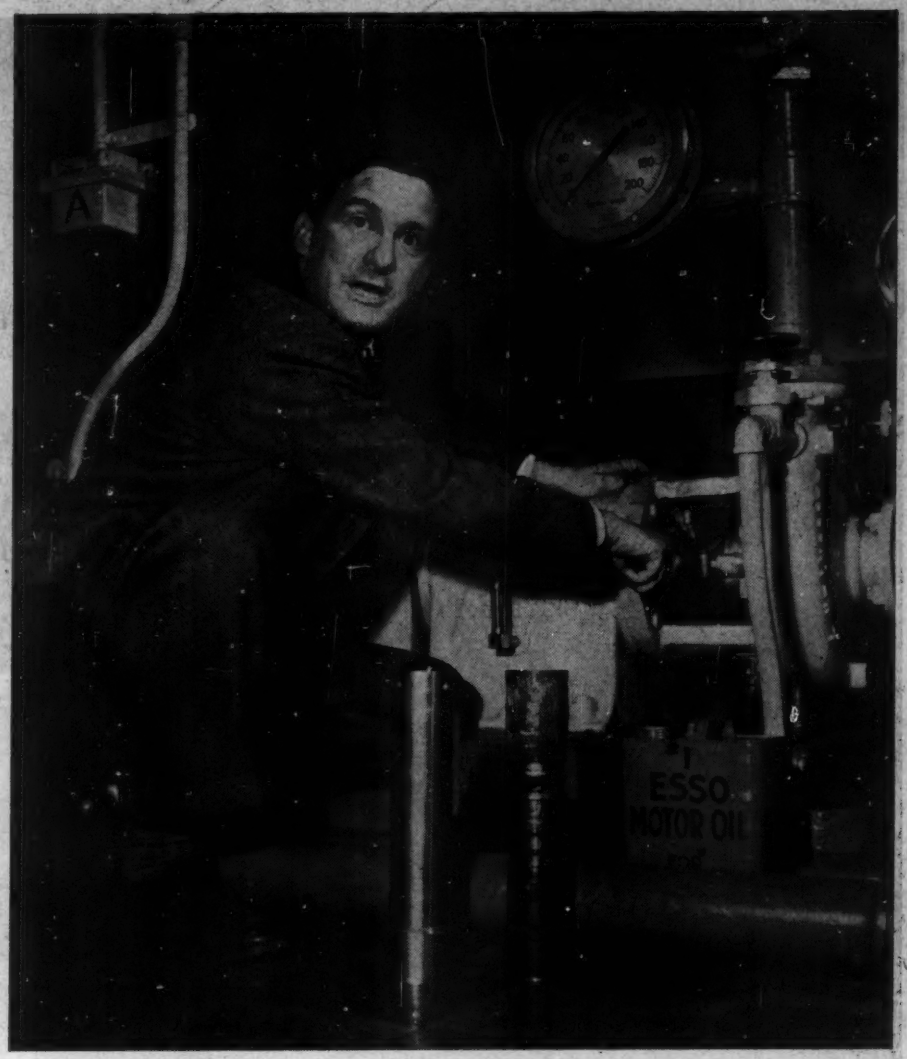
At the right Louis H. Zepfler is counting the strokes per minute while the pump strokes are mounting.

foot head. Its operating speed was 1750 rpm, full load 12.5 amp. 440 volts. An ammeter, connected to the motor, was used to demonstrate proper and improper operation when starting and during operation of this pump. A temperature indicator-recorder was connected at both the pump stuffing box and the gland.

The pumps were mounted on wooden foundations and equipped with drain pans, so as to stimulate actual plant operating conditions. Brightly colored lubricant containers, with the name of the lubricant stenciled on each, were kept adjacent to the pumps.

Next a tentative course was outlined by the instructors and timed for a series of three one-hour sessions. The instructors alternately wrote and rewrote the course, trying it out on each other and upon the management. When smoothed out, it was reduced to a manual form which was printed complete with a timetable to show exactly how much time to spend on each point, complete directions for the instructor, and text for the essential points to be covered.

The reason for this rigidity and uniformity of presentation was to achieve an integration so that all who took the training course received exactly the same instruction. The heart of a preventative-maintenance program, it was learned, is an agreement between an employe and his supervisor and between employes of different departments as to what exactly constitutes the "right" method, and what a certain danger signal portends.



The wrong way to tighten the packing gland on a centrifugal pump is demonstrated by George A. Lloyd, light oil treating department.

The Bayway course was not entirely visual training; in fact auditory training—the interpretation of sounds in a pump or motor—constituted one of the most important parts of the course. At the expense of perhaps slight damage to the demonstration equipment, the instructor often operated it the wrong way to fix in the men's ear the peculiarities of the various danger sounds. The sound of a faulty ball bearing was demonstrated by spinning a noisy, scored bearing and then spinning a good bearing that is silent in operation.

One of the most convincing demonstrations in the Bayway course, to judge from the interest it created in the classroom, was the one on overspeeding of the steam pump. In this discussion, the instructor explains what he is going to demonstrate, starts the pump and when it reaches its efficient operating rate of 48 rpm, readings are taken from the various gauges in gallons per hour of throughput and pounds of steam consumed per hour. Then the pump is speeded to approximately 60 rpm while the same readings are taken at that speed. When tabulated, as below, loss of efficiency and waste of power becomes immediately evident.

Speed RPM	Steam Lbs./Hr.	Flow Gals./Hr.	Pounds Steam Per 100 Gals.
48	100	2800	3.6
60	350	3200	10.9
Steam wasted	....	....	7.3

The course includes many demonstrations of this nature not only in connection with the operation of the motors and pump, but also on the operation of various valves, right and wrong way to make gland adjustments, motor-switch operation, effect of loss of suction, etc.

The course is actually very brief and takes up in sequence, the steam pump, the electric pump, and the steam turbine, with information on valves and other equipment woven into the main themes. When first given last winter at Bayway the classes consisted of 12-22 men each, were held outside of working hours, and compensation was on the basis of overtime pay. Altogether more than 570 have attended the course and they probably will be given refresher training from time to time.

A very natural psychological handicap for the instructors arose from the fact than many of the men attending the classes had been operating pumps for 10 to 15 years and with that experience behind them they were not always convinced that they needed training after that many years. This called for the exercise of considerable discretion on the part of the instructors, who were careful to inflate rather than

The class gets a demonstration in the proper procedure for starting a motor driven centrifugal pump.

deflate any oldtimer's pride in his operating knowledge. The right way of operating a pump or valve was presented, not as the way the instructors had figured it out, but as the way the manufacturer of the equipment recommends.

The sessions were completely informal and every one was encouraged to talk at any time, which they did on many occasions, especially when an instructor himself did something wrong. On one occasion a member of the class took definite exception to a step in the recommended way of starting a certain unit. He was given a chance to prove his procedure was better, which he did, and his method was then incorporated into the instruction manual, and thus was passed on to other groups.

At the conclusion of the course a small folder suitable for carrying handily in the pocket was given to each person to remind him of some of the points made in the course, and covering also the recommended speed of steam-driven pumps.

While actual cost comparison figures are not yet available to indicate what the course has achieved in that direction, the very definite reduction in certain types of failures has already proved its worth. Other indications have been evident in various employes reactions. Since completion of the first series of sessions on steam pumps, a marked improvement in operating speeds has been noticed at the refinery. There has been an increase in the realization that the recommended types of lubricants, must be used and other good signs have been evident. Within a week after the motor-pump sessions, three serious breakdowns were averted by men making use of their new knowledge. Two of these concerned an unusual operating noise they had been cautioned to notice.

On one occasion an operator detected in his pump an unusual noise, and, mindful of the training course, he called in the machinist to locate the trouble. The latter said that the pump sounded all right to him and would go no further to investigate. The operator thereupon went to his department head and said that he was sure something was wrong with his pump. The department head then had the pump dismantled and it was found that an impeller nut had shaken loose and the centrifugal vanes were very near to flying loose in the cage and causing complete damage to the unit. The machinist came around shortly afterward to apologize and add: "It won't happen again with me."

Simple as the incident appears, it shows that the effectiveness of a preventive-maintenance course depends very greatly upon complete integration of the preventive rules so that there is a minimum of disagreement all the way around.

Time Saving Computing Instruments For Spectroscopic Analysis

T. D. MORGAN and F. W. CRAWFORD

Research Department, Phillips Petroleum Company

CHEMICAL plants over the country, having reached an all time high in the production of war materials, depend on rapid analytical methods as a guide in keeping "on stream." Successful applications of spectroscopic methods to these analytical problems have shortened the time interval from sampling to completion of an analysis at a big saving in technical manpower. The principal time consumed now in a multicomponent analysis by spectrophotometry is due to the rather lengthy computations. Several short-cut mathematical methods have been developed in attempts to reduce further the over-all time for completion of an analysis, but this paper presents a method of demonstrated usefulness as well as a description of electrical computing instruments for carrying out the steps of the method.

One instrument herein described will in principle quickly solve any set of simultaneous equations of the type ordinarily encountered in either absorption spectrophotometry or mass spectrometry. In particular, an instrument for solving seven equations in seven unknowns has been developed and its practicability demonstrated in field tests at the Plains Butadiene Plant Laboratory, Borger, Texas. Also, a second instrument has been developed for reducing spectrophotometer data to extinctions.

WHEN an infrared spectrophotometer is used for making analyses of multi-component mixtures the data consist of galvanometer deflection readings. These deflections are caused by approximately monochromatic infrared light reaching a sensitive thermocouple. Two deflections are read at each pre-selected wave length; one (I_0) with an evacuated cell in the light path and the other (I) with the same cell containing the unknown mixture in the path. The extinction (K) of the absorbing gas is defined as log $\frac{I_0}{I}$.

The computation necessary to get these extinctions may be done by logarithms, slide rule or by the electrical computing machine explained below in which every mathematical operation in the above computations has an electrical or mechanical counterpart.

By way of illustration, here is a set of simultaneous equations such as are encountered in the process of analysis by infrared spectrophotometry. These equations are set up from instrument calibration and sample data where

x, y, z . . . are percents of the components of the mixture

A, B, C . . . are extinction coefficients from instrument calibration

K . . . are extinctions measured at appropriate wave lengths for a particular sample.

$$\begin{aligned} A_1x + B_1y + C_1z + \ldots\ldots &= K_1 \\ A_2x + B_2y + C_2z + \ldots\ldots &= K_2 \\ A_3x + B_3y + C_3z + \ldots\ldots &= K_3 \\ A_nx + B_ny + C_nz + \ldots\ldots &= K_n \end{aligned} \qquad (1)$$

The method and machine of this paper work best when, in these equations, A_1, B_2, C_3 . . . are large compared to the other constants.

Method of Computation by Successive Approximations

The method of solution herein outlined consists in systematically making successive approximations to the correct solution of the problem. By this method it is first assumed in Equations (1) that the extinctions of all the components except x are negligible, so that to a first approximation $x' = \frac{K_1}{A_1}$. (Primes of the variables x, y, z . . . will be used to indicate the order of approximation.) In the second of Equations (1) assign the value of x′ to x and assume that the extinctions of all the components except x and y are negligible so that

$$y' = \frac{K_2}{B_2} - \frac{A_2}{B_2}x'.$$

In the third of Equations (1) assign $x = x'$ and $y = y'$ and assume that all extinctions are negligible except those of x, y and z; then

$$z' = \frac{K_3}{C_3} - \frac{B_3}{C_3}y' - \frac{A_3}{C_3}x'.$$

This procedure is repeated for each equation until a first approximation for each component has been found. A second approximation of x, designated as x″, is computed by assigning the first approximation to all the components except x, which yields:

$$x'' = \frac{K_1}{A_1} - \frac{B_1}{A_1}y' - \frac{C_1}{A_1}z'.$$

Similarly a second approximation is found for each component. It will be found that after a few approximations have been calculated, each successive approximation yields values not much different from the answers of the preceding approximation. The experimental errors of the original data determine when it is impractical to carry successive approximations further. The accuracy usually will be of the order of one percent when the spectrophotometer is of the small routine type.

The mathematical representation of what happens when successive approximations are made is illustrated by a consideration of the following set of two simultaneous equations with two unknowns. A two-equation system was chosen for this presentation for simplicity although the expansion may be carried out for a system containing more than two unknowns with similar conclusions.

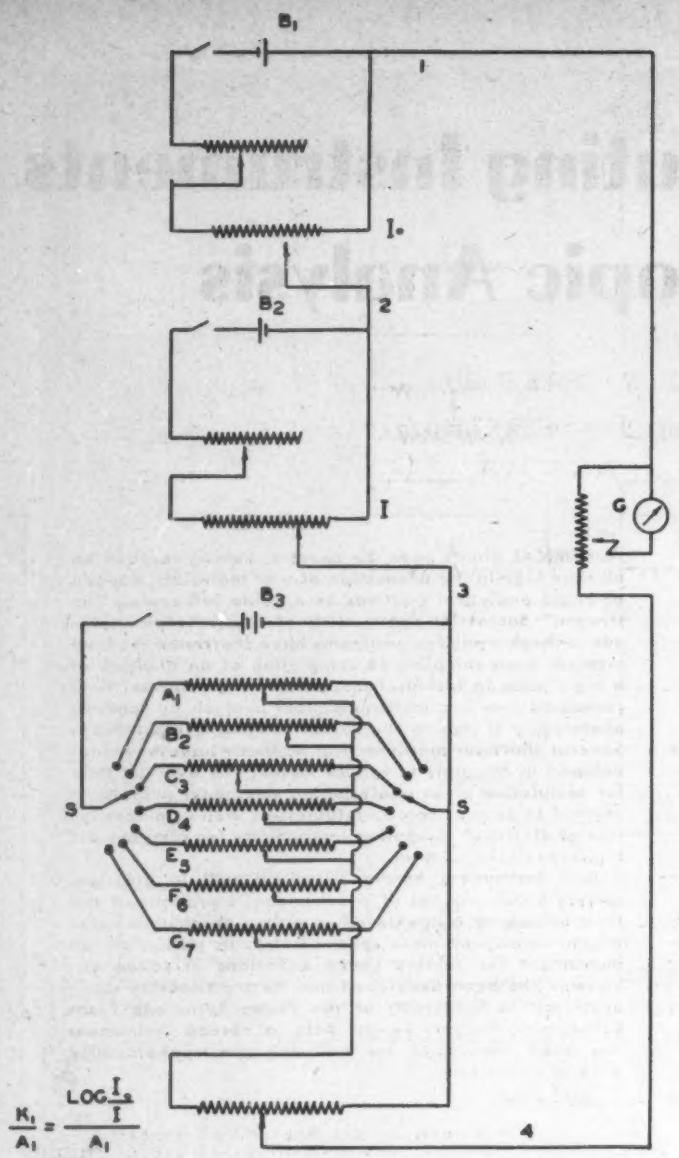


FIGURE 1
Electrical Diagram of Extension Computer

Beginning with x and carrying out a number of successive approximations to y in the system;

$$\begin{aligned} A_1x + B_1y &= K_1 \\ A_2x + B_2y &= K_2 \end{aligned} \qquad (2)$$

the mth approximation of

$$y = \frac{K_2}{B_2} - \frac{A_2K_1}{B_2A_1} + \frac{A_2B_1K_2}{A_1B_2^2} - \frac{A_2^2B_1K_1}{A_1^2B_2^2} + \frac{A_2^2B_1^2K_2}{A_1^2B_2^3} - \frac{A_2^3B_1^2K_1}{A_1^3B_2^3} + \frac{A_2^3B_1^3K_2}{A_1^3B_2^4} - \frac{A_2^4B_1^3K_1}{A_1^4B_2^4} \cdots \frac{A_2^{m-1}B_1^{m-1}K_2}{A_1^{m-1}B_2^m} - \frac{A_2^mB_1^{m-1}}{A_1^mB_2^m}K_1$$

As a test for convergence in the foregoing series let us consider the ratio of the last term of the series to the next to the last term:

$$\frac{A_2K_1}{A_1K_2}$$

or substituting equivalent values for K_1 and K_2:

$$\frac{A_2A_1x + A_2B_1y}{A_2A_1x + A_1B_2y}$$

If this ratio is less than one or if $A_2B_1 < A_1B_2$, the series converges. In the general set of Equations (1) if $A_1 > B_1$, $A_1 > C_1$ . . . and $B_2 > A_2$, $B_2 > C_2$ . . . and $C_3 > A_3$, $C_3 > B_3$ . . . the series of successive approximations converge rapidly so that the method yields a sufficiently accurate solution to the simultaneous equations in a few computation cycles. In infrared spectroscopy this means that if wave lengths can be chosen at which only one component causes chief absorption, then the above method of calculation may be used to advantage.

It is found in practice that the order in which the Equations (1) are placed influences to a large extent the number of successive approximations required to obtain correct answers. While an attempt is made to select a wave length for each component at which only that component causes chief absorption, it is not always possible to do this. Consideration of Equations (2) in the following form will illustrate how the order of calculation changes the number of successive approximations required to obtain a satisfactory solution.

$$\begin{aligned} x + \frac{B_1}{A_1}y &= \frac{K_1}{A_1} \\ \frac{A_2}{B_2}x + y &= \frac{K_2}{B_2} \end{aligned} \qquad (3)$$

In this set of equations if $\frac{B_1}{A_1}y$ is very small compared with K_1/A_1 then the first approximation of x is very nearly correct as also is the first approximation of y. If

$$\frac{B_1y}{A_1x} < \frac{A_2x}{B_2y}$$

a correct solution to the equations may be found with fewer successive approximations when x′ is found first than when y′ is found first. Since the variables appear in the above condition, it is necessary to have a rough knowledge of sample composition in order to make the best selection of calculating order.

Electrical Computing Machines

All of the mathematical operations of this computation method may be carried out by the proper addition and subtraction of electrical potentials. We use two machines for this; one to convert spectrophotometer readings to extinctions, necessary only in absorption spectroscopy, and the other to solve the resulting simultaneous equations. The first of these, the wiring diagram of which is shown in Figure 1, is used to take the logarithm of the ratio I_0/I and divide this by a cosntant. This converts I_0 and I readings from the spectrophotometer into K_1/A_1, K_2/B_2, etc., of Equations (3). To do this, two linear voltage dividers with logarithmic scales are arranged so that the potential of one is subtracted from the potential of the other. (Logarithmic voltage dividers with linear scales could also be used.) Referring to Figure 1 the potential between points 1 and 3 is proportional to $\log I_0/I$.

To set the computer for a given value of A_1 it is necessary only to set potentiometers I_0 and I at typical values, then set potentiometer

$$\frac{K_1}{A_1} = \frac{\log I_0 - \log I}{A_1}$$

and adjust potentiometer A_1 until the galvanometer reads zero. The functional details of this circuit can be followed by a straight forward application of Kirchhoff's laws.

Figure 2 is a wiring diagram of the electrical com-

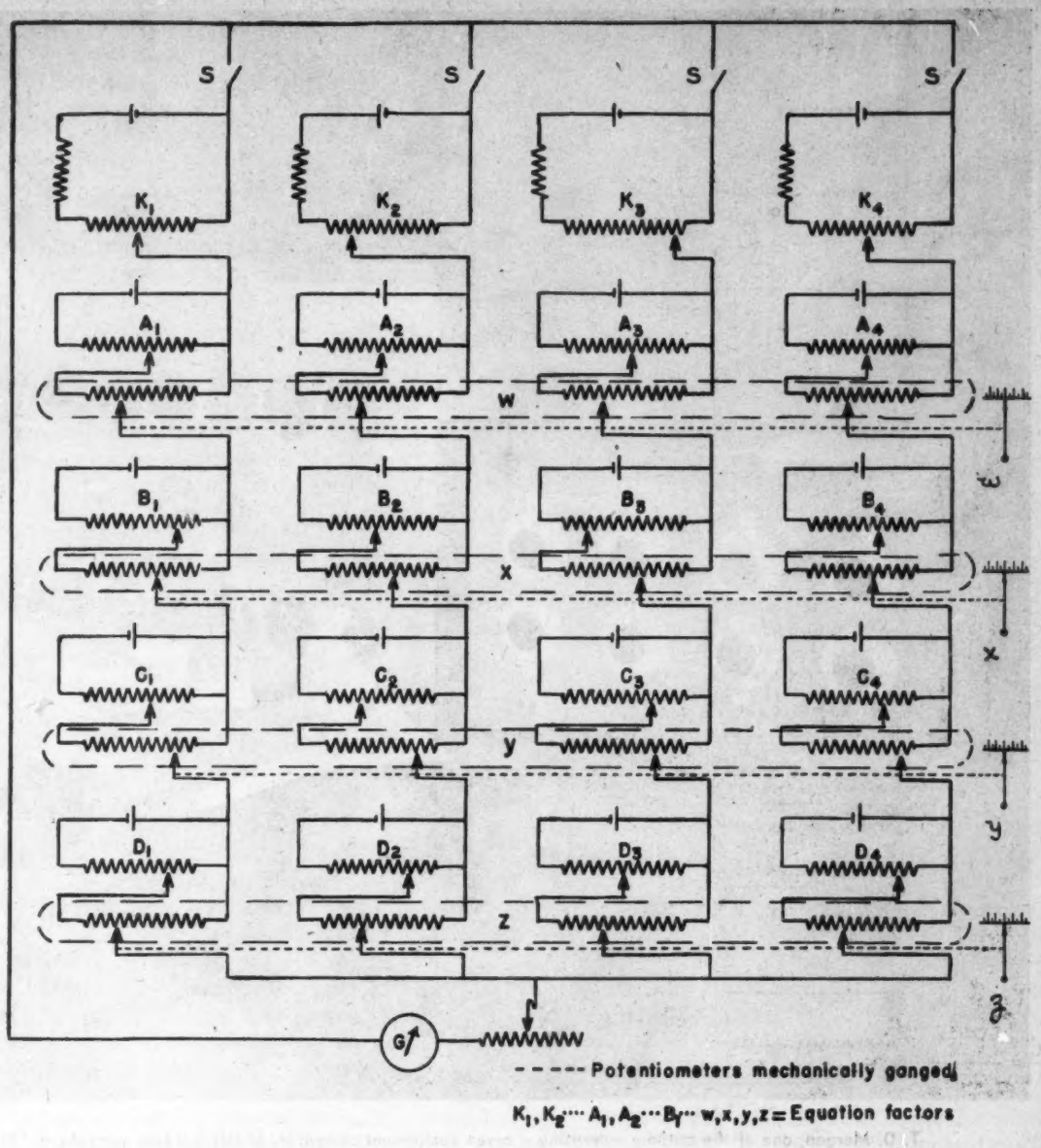


FIGURE 2

Electrical diagram of computer for four linear simultaneous equations with four unknowns.

puting instrument for solving simultaneous equations. A four-component system was chosen for purpose of illustration although the instrument was actually built for seven components. In the following set of equations all variables and coefficients are real.

$$w + \frac{B_1 x}{A_1} + \frac{C_1 y}{A_1} + \frac{D_1 z}{A_1} = \frac{K_1}{A_1}$$

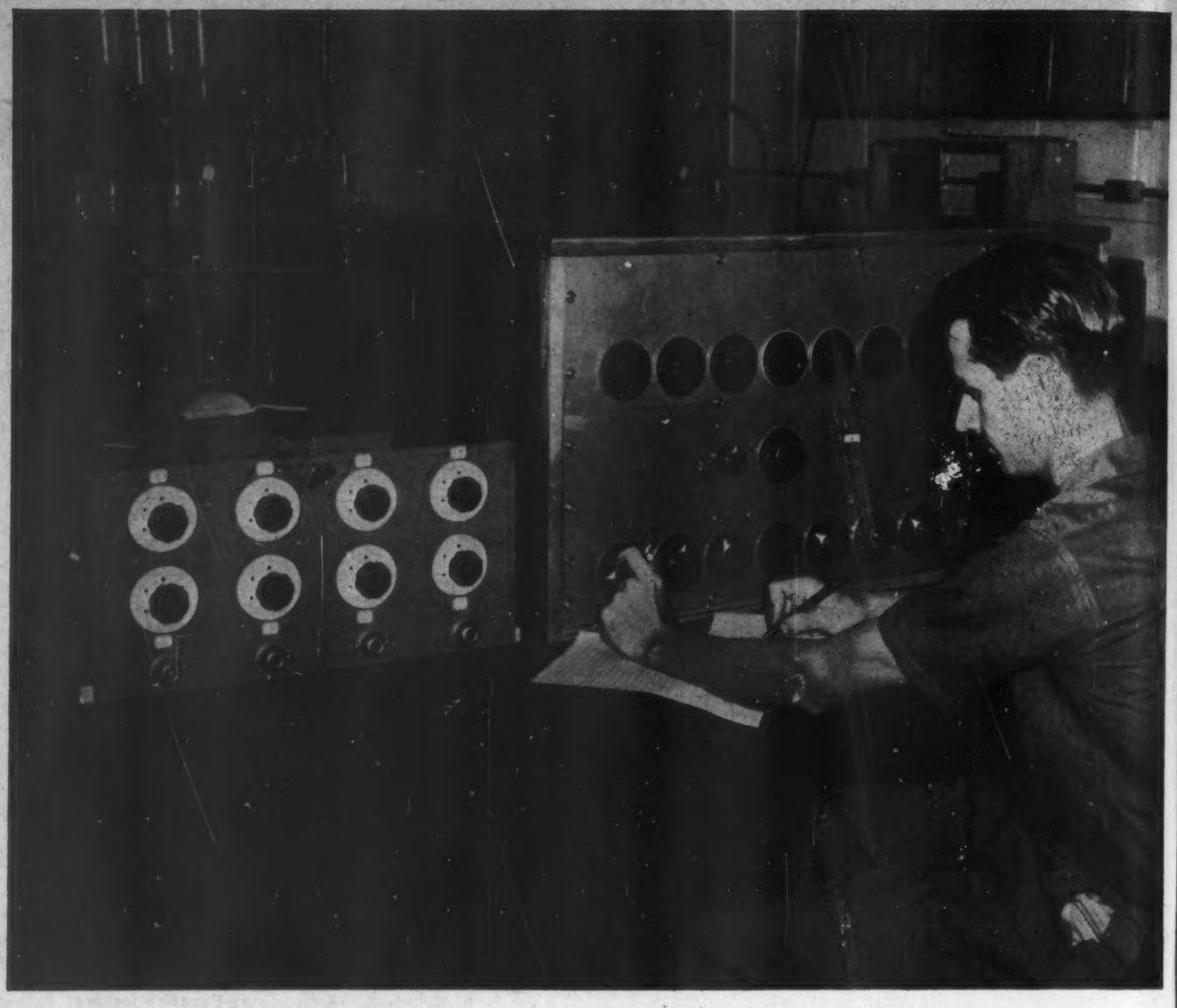
$$\frac{A_2 w}{B_2} + x + \frac{C_2}{B_2} y + \frac{D_2}{B_2} z = \frac{K_2}{B_2}$$

$$\frac{A_3}{C_3} w + \frac{B_3}{C_3} x + y + \frac{D_3}{C_3} z = \frac{K_3}{C_3}$$

$$\frac{A_4}{D_4} w + \frac{B_4}{D_4} x + \frac{C_4}{D_4} y + z = \frac{K_4}{D_4}$$

The A's, B's, C's and D's of these equations are proportional to the extinction coefficients of w, x, y and z respectively, at wave lengths L_1, L_2, L_3 and L_4. K_1, K_2, K_3 and K_4 represent total extinctions of the sample at wave lengths L_1, L_2, L_3 and L_4, respectively. Negative quantities may be handled by the use of reversing switches on the cells of Figure 2. Expansion of the computer for use with a greater number of components is straight-forward. For example to convert the computer of Figure 2 to one for 5 components, each vertical row of Figure 2 would be expanded to contain 5 battery circuits (in addition to the K circuits) and there would be 5 vertical rows instead of 4. Referring to Figure 2, it will be noticed that each vertical row contains 5 cells; the polarity of these cells is dependent upon whether positive or negative terms appear in the equation. Figure 2 is arranged for all positive terms so the polarity of the potentiometers representing total extinction is the reverse of the polarity of all the other potentiometers. Each cell is connected across a combination of two potentiometers, each of which is set to a value proportional to its counterpart in the equations. Of each pair of potentiometers the one closest to the cell should be low in resistance compared to the other one for the system to perform exactly according to the theory of the computational method but in the present instrument all the potentiometers are alike and no problems have been encountered which would not converge to a solution on the computer. This makes it possible to order a large number of one kind of potentiometer and select the best ones for critical parts of the circuits.

When the total potential from all of the cells of



T. D. Morgan, one of the authors, operating a seven component computer. At left is a four component, "breadboard" model.

one circuit is zero, indicated by zero galvanometer deflection, the equation represented by the circuit is balanced. When all circuits are in balance, all equations are balanced and the solution may be read off of the dials.

Details of Setting Coefficient Potentiometers

Calibration of the computer of Figure 2 is done by setting the dials on the "A," "B," "C" and "D" potentiometers according to the spectrometer calibration data. This may be done by assuming in Equations (4) that all the variables except w are zero and hence that w equals 100 percent. The right hand member of each equation is then known and these values are set up on the respective dials of the "K" potentiometers in Figure 2. Each circuit is then balanced by adjusting the dials on the "A" potentiometers. It is next assumed that x is 100 percent and the "B" potentiometers set, then y and z are each assumed to be 100 percent while the "C" and "D" potentiometers are set.

Operation of Computer

To use the computer on infrared spectroscopic data, I_0 and I are first reduced to extinctions and divided by the extinction coefficients of principal absorbers on the computer as outlined above. These values are then equivalent to the right-hand members of Equations (4) and are set on the respective dials of the "K" potentiometers of Figure 2. In Figure 2, switch S_1 is closed and galvanometer G is zeroed by adjusting the dial of the "w" potentiometers. Then S_1 is opened and S_2 is closed and the galvanometer is zeroed by adjusting x. Circuits 3 and 4 are balanced in a similar manner by adjusting y and z respectively. Returning to circuit 1 it will be found that the galvanometer no longer reads zero when S_1 is closed, so w is again adjusted to balance the circuit. These zeroing manipulations are repeated until the galvanometer reads zero without turning a dial as each switch is separately closed. When this condition has been reached the solution to the set of simultaneous equations may be read directly from the dials w, x, y and z. Each cycle of these manipulations amounts to obtaining an approximation in the computational method above. Seven circuits can be balanced in about one minute and three cycles are usually sufficient to arrive at the answer.

The computation method shown here has been in use for nearly a year. Recently the electrical computing machines were given field tests at the plant and have already saved much time in making analyses.

Engineering and Construction Of the Santa Maria Valley Absorption Plant

D. E. McFADDIN
Union Oil Company of California

THE Santa Maria Valley oil field was discovered by Union Oil Company of California in 1934. The oil from this field is about 15° API gravity, and has a high sulphur content. During the first three years of the life of the field there was practically no demand for oil of this character and production was at a minimum. However, with the coming of World War II the demand increased so that now there is urgent demand for the maximum of oil production. Conservation and proper utilization of the gas associated with the increased oil production has consequently required installation of gas-treating and handling facilities.

In 1937, gas equipment was installed to compress 5 million cubic feet per day of wet gas from 20 pound gauge to 150 pounds, and to remove the hydrogen sulfide by means of an iron- oxide bed and then to transport the gas to Union Oil Company's Orcutt absorption plant to recover the gasoline content and to deliver the surplus dry gas into Southern Counties Gas Company lines. This operation was satisfactory for several years, but by the early part of 1942 production had increased until it was apparent that a complete absorption plant was needed in Santa Maria Valley. At this time very little new material was available for constructing an absorption plant, and it was necessary to comb the country for idle used equipment. Nearly all major units were obtained from idle equipment which had previously been in service many years. All of this equipment was thoroughly reconditioned in Union Oil Company salvage shops at Santa Fe Springs. In some cases, 15-year-old "bare-rod" welding on pressure vessels was found to have a tensile strength insufficient to meet the desired working pressure. This bare-rod welding was chipped out and the vessels rewelded according to modern standards. Pumps, safety valves and instruments were also a very difficult problem and many items of this class were rebuilt in Union Oil Company shops from equipment which had long been discarded. Engineering and process and construction of a plant with such a limited availability of equipment presented many unusual problems. Nevertheless, necessary priorities were obtained and construction was started on April 15, 1943, and the plant was completed and put into operation December 30 of the same year.

THIS description of the absorption plant in the Santa Maria Valley was given at the July, 1944 meeting of the California Natural Gasoline Association.

The equipment was assembled from several sources, most of them having had previous service. The complete paper included a tabulation of the source and condition of the principal units, now operating at Santa Maria.

Small Plant

Santa Maria Valley absorption plant was designed to process a maximum of 18 million cubic feet per day with an absorption-oil circulation of 16,000 gallons per hour and an absorber pressure of 190 pounds gauge; extracting 80 percent of the iso-butane content, 97.5 percent of the normal butane and 99.2 percent of the pentanes and heavier content of the gas.

TABLE 1
Overall Plant Commodity Balance, Santa Maria Valley Absorption Plant

COMPONENT	18,000,000 CF/DAY INTAKE GAS			EXTRACTED PRODUCTS				17,280,000 CF/DAY DISCHARGE GAS		
	Gas Vol. Percent	Gal./Mcf	Gal./Day	29# Reid Gaso. Gal./Day	Iso-Butane Side Cut Gal./Day	Total Liquids Gal./Day	Liquid Extraction Percent	Gas Vol. Percent	Gal./Mcf	Gal./Day
Hydrogen Sulfide	25gr/100C.F.	.....	.....	.....	.....	.....	.....	.00	.....	.....
Water Vapor	0.30	.....	.....	.....	.....	.....	.....	.05	.....	.....
Air	1.00	.....	.....	.....	.....	.....	.....	1.00	.....	.....
Carbon Dioxide	8.80	.....	.....	.....	.....	.....	.....	9.20	.....	.....
Methane	79.83	.....	.....	.....	10	10	.....	83.10	.....	.....
Ethane	3.87	.....	.....	.....	25	25	.....	4.02	.....	.....
Propane	3.19	.....	.....	.....	1,120	1,120	.....	2.48	.....	.....
Iso-Butane	0.51	0.167	3,006	240	2,166	2,406	80	0.11	0.035	600
Nor-Butane	1.22	0.383	6,894	6,200	524	6,724	97.5	0.03	0.01	170
Pentane and Heavier	1.28	0.500	9,000	8,930	.....	8,930	99.2	0.01	0.004	70
Total	100.00			15,370	3,845	19,215		100.00		

TABLE 2

Recycled Vapors, Santa Maria Valley Absorption Plant

	Rich Oil Fractionator Vapors	Raw Gasoline Accumulator Vapors
Analysis	**Mol Percent**	**Mol Percent**
Water Vapor	0.50	0.50
Carbon Dioxide	12.60	5.80
Methane	49.64	17.50
Ethane	12.64	11.23
Propane	20.72	36.13
Iso Butane	1.40	9.38
Nor Butane	1.93	15.75
Pentanes and Heavier	0.57	3.71
	100.00	100.00
Gallonage Content	**Gal./Mcf.**	**Gal./Mcf.**
Iso Butane	0.456	3.055
Nor Butane	0.607	4.954
Pentanes and Heavier	0.207	1.349
Gas Rate, Mcf./Day	610	280
Recycled Gallonage	**Gal./Day**	**Gal./Day**
Iso Butane	278	855
Nor Butane	370	1390
Pentanes and Heavier	126	378

Table 1 gives the over-all plant commodity balance. Gas from the field reaches the plant at approximately 23 pounds gauge, and is compressed to 210 pounds in two stages. At the interstage pressure of about 75 pounds the gas is countercurrently contacted with 4 percent soda ash solution to remove the major portion of the hydrogen sulfide. The remainder of the hydrogen sulfide is removed by iron-oxide beds after the gas has been compressed to 210 pounds. The isobutane and heavier fractions of the gas are then extracted from the gas by absorption oil circulated through absorbers operating at about 190 pounds. The water-vapor content of the absorption-plant-discharge gas is then removed in a Southern Counties Gas Company gas dehydration plant, employing diethylene glycol, in order to prevent subsequent condensation and corrosion in the fuel system. A large portion of the plant-discharge gas is used in the Santa Maria Valley area for domestic and industrial purposes. The remainder is transported to Orcutt compression plant where it is compressed to 400 pounds and delivered to Southern Counties Gas Company's main lines running to Santa Barbara.

Simple Plant Cycle

The flow chart, Figure 1, shows that the absorption plant cycle is quite simple. There are two absorbers. Each is 46 inches I.D. and 24 feet high and contains 15 perforated trays. Absorption oil is metered to the top of each absorber and flows from tray to tray downward, countercurrently against the rising gas. Liquid-level controllers automatically hold a constant oil level in the bottom section of each absorber. The main stream of enriched oil from the bottoms of the absorbers flows through interchangers where it is heated to approximately 290° F. It then flows into a rich-oil fractionator at 100 pounds pressure. This unit separates the major portion of the methane and ethane from the absorption oil and other absorbed fractions. Gasoline content of the gas from the field is unusually low. This fact has a direct bearing on the condensation and separation of the gasoline and iso-butane and propane from the lighter absorbed fractions. When theoretical computations were made to determine the proper process cycled it was found that either a high pressure (100-pound) still, a rich-oil fractionator or some other facility was required to eliminate the major portion of the methane and ethane from the cycle before the main (40-pound) raw gasoline condenser was reached. Otherwise these light fractions would prevent satisfactory condensation of the other fractions, especially of propane and the butanes. The use of a 32-inch I.D. rich-oil fractionator was found to be the best suited. The rich oil and vapor from the interchangers at 290° F. enters the bottom section of the column where the liquid is separated from the vapor. The liquid flows out the bottom of the preheaters while the vapor rises through fractionating trays countercurrently against a stream of cold rich-oil which flows direct from the 190-pound absorbers to the top of the rich-oil fractionator. Table 2 gives the analyses and rates of the rich-oil fractionator vapor and the raw-gasoline-accumulator vapor. From these analyses it is computed that 86 percent of the methane and 71 percent of the ethane are removed by the rich-oil fractionator. The vapor from the top of the rich-oil fractionator is commingled with the interstage untreated gas at 70 pounds pressure and is compressed and recycled through the absorbers. A heater, condenser, accumulator and pumps are not required for this unit and its operation is simple. At some future date it can be readily converted to a pressure still in order to produce propane liquid, by installing a 100-pound condenser and accumulator, in which case a small portion of the raw gasoline production from the low-pressure stripping still would be used as reflux for the high-pressure still, and the remainder of the raw gasoline from the low-pressure stripping still would be circulated through the 100-pound pressure condenser to serve as an absorbing medium for propane. The stabilizer would then be fed from the 100-pound accumulator.

Fractionating-Stripping

The rich oil from the bottom of the rich-oil fractionator flows through steamheated preheaters into the main stripping and fractionating still where the raw gasoline fractions are removed from the absorption oil. The fractionating-stripping still is 60 inches in diameter and 55 feet high. It has 19 perforated trays, 13 of which are above the feed inlet. A water draw-off tray is located immediately below the seventh tray from the top, leaving 6 trays between the feed inlet and the water draw-off tray. The still also has built-in oil reheaters located below the feed inlet. One is located between the second and third tray from the bottom and another is located below the bottom tray. It was realized that the heaters in this still are not ideally located, the optimum location being about two trays down from the feed. However, the cost of changing the location of the heaters would have been prohibitive and it was therefore decided to use the still as designed. Exhaust steam at 50 pound gauge from the lean-oil pumps is metered into the bottom section of still and rises through the perforations of the trays in order to strip all of the raw gasoline fractions from the oil. The still operates at 45 pound gauge with a bottom temperature of 350° F. and a top temperature of 170° F. The top temperature is maintained automatically by a temperature controller which regulates the amount of raw or stable gasoline used as reflux to the top of the still. The bottom section of the still provides surge capacity for the system and the level at this point varies according to the amount of oil in the system.

PROCESS FLOW DIAGRAM
SANTA MARIA VALLEY ABSORPTION PLANT

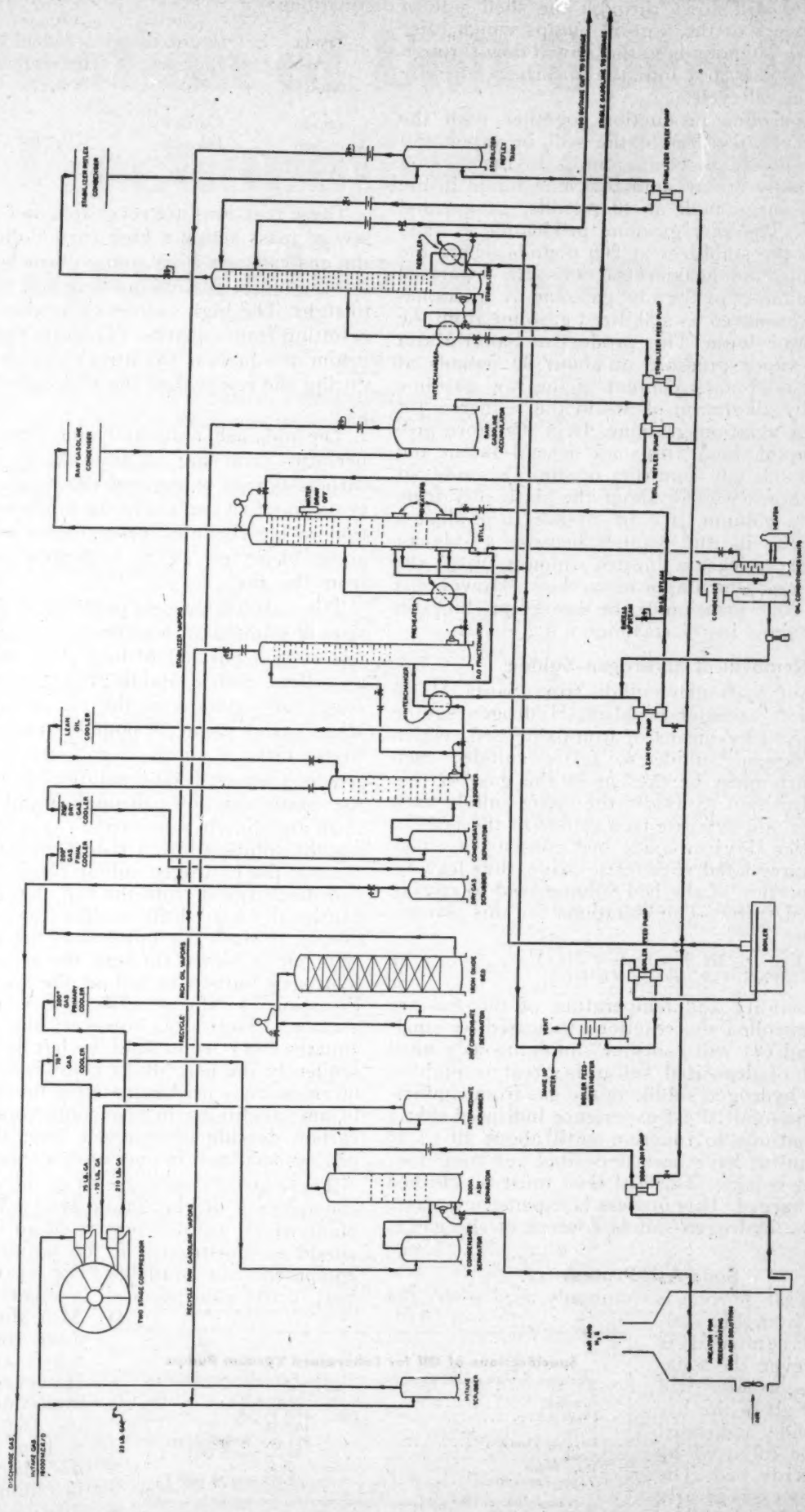


FIGURE 1

The hot lean oil from the bottom of the fractionating-stripping still flows through the shell side of the interchangers to the lean-oil pumps which raise the pressure to 250 pounds so that it will flow through the lean-oil coolers and into the absorbers, thereby completing the oil cycle.

The raw gasoline production together with the still reflux leave the top of the still in vapor and are then condensed in cooling units in the cooling tower and finally are accumulated as a liquid in the raw-gasoline surge tank at 40 pounds, gauge, and about 65° F. The raw gasoline production is then pumped into the stabilizer at 200 pounds where the normal butane and heavier fractions are separated from the remainder of the raw gasoline by fractionation and are produced as stabilized gasoline from the bottom of the column. This product at Santa Maria has a Reid vapor pressure of about 30 pounds at 100° F. The iso-butane content of the raw gasoline is required by alkylation plants in the refineries for production of aviation gasoline. It is therefore produced as a liquid along with some normal butane and propane as a side cut from the column. This side-cut liquid is withdrawn from about the sixth tray from the top of the column. It is impossible to produce a pure is-obutane in this manner because a side-cut must contain at least a limited amount of all the lighter fractions which appear overhead. However, a satisfactory concentration of the desired product can often be obtained in this manner.

Removal of Hydrogen Sulfide

Removal of hydrogen sulfide from Santa Maria gas constitutes a major problem. Hydrogen sulfide can be removed by means of iron-oxide beds which convert hydrogen sulfide to ferric sulfide; then oxygen, which must be present in the gas for this process to function, converts the ferric sulfide back to iron oxide and deposits free sulfide in the bed. In actual practice the iron-oxide bed consists of wood shavings impregnated with ferric oxide, thus leaving a large proportion of the bed volume void to receive the deposited sulfur. The equations for this process are as follows:

$$Fe_2O_3 + 3H_2S \rightarrow Fe_2S_3 + 3H_2O \quad (1)$$
$$2Fe_2S_3 + 3O_2 \rightarrow 2Fe_2O_3 + 6S \quad (2)$$

If the humidity and temperature of the gas are properly controlled the reactions indicated by equations (1) and (2) will continue simultaneously until the amount of deposited sulfur is great enough to prevent the hydrogen sulfide in the gas from contacting the ferric oxide. Past experience indicated that a bed will continue to function until about 20 to 25 pounds of sulfur have been deposited per cubic foot of total bed volume. The bed then must be cleaned out and recharged. This process is expensive in cases in which the hydrogen-sulfide content of the gas is high.

Soda-Ash Process

The soda-ash process is commonly used where the amount of hydrogen sulfide to be removed is great. However, the soda-ash process usually will not remove all of the hydrogen sulfide and must therefore be followed by an iron-oxide bed. The soda-ash process is greatly complicated by the presence of CO_2 in the gas as is indicated by the following equations:

Soda Ash		Hydrogen Sulfide		Sodium Hydrosulfide		Sodium Bicarbonate	
Na_2CO_3	+	H_2S	→	$NaHS$	+	$NaHCO_3$	(3)

Soda Ash		Carbon Dioxide		Water		Sodium Bicarbonate	
Na_2CO_3	+	CO_2	+	H_2O	→	$2NaHCO_3$	(4)

These reactions are reversible and according to the law of mass action a high carbon-dioxide content of the gas causes a high sodium-bicarbonate concentration as indicated by equation (4), moving from left to right. The high sodium-bicarbonate concentration resulting from equation (4) shifts the reaction equilibrium of equation (3) from right to left, thereby reducing the removal of the hydrogen sulfide from the gas.

The soda-ash units at Santa Maria were found to perform according to this theory. The 8 percent carbon-dioxide content of the Santa Maria gas converts about 99 percent of the 4 percent soda-ash solution to bicarbonate. Nevertheless with this mixture about 70 percent of the hydrogen sulfide is removed from the gas.

The soda-ash process provided at Santa Maria consists of pumping a 4 percent soda-ash solution to the top of two parallel 81-inch diameter contactors or absorbers, each containing six perforated trays. The contactors operate on the cooled compressor interstage gas at about 70 pounds gauge, and a solution-to-gas ratio of about 35 gallons per thousand cubic feet is employed. The solution from the bottom of the contactors flows through liquid level controllers to an areator where equation (3) is reversed by spraying the solution into a rising current of air, so as to remove the hydrogen sulfide from the field of action and discharge it from the top of the areator. A conventional forced-draft cooling tower with a 50-foot discharge stack is employed as the areator and sufficient air is blown through the areator to dilute the hydrogen sulfide to below the toxic danger limit. Equation (4) theoretically also is reversible in the areator. Practically, however, the reaction rate of equation (4) from right to left is very slow. Consequently the percentage conversion of carbonate to bicarbonate is predominately a function of the equilibrium conditions in the contactors, and very little carbon dioxide is removed from the gas after the process has been in operation a short time.

There are certain features of the processes and the construction of the Santa Maria Valley absorption plant which are different from an ideal plant which would be constructed if the required materials and equipment are available. For example, direct-fired heat of the absorption oil is superior to steam heat. Also, absorbers with 20 or more trays instead of 15 trays are advantageous. However, in spite of these limitations, the plant was successfully constructed and put into operation under adverse conditions and is adding its share of production to the war effort.

Specifications of Oil for Laboratory Vacuum Pumps

Gravity	25.6° A.P.I.
Flash	410° F.
Fire	460° F.
Saybolt Viscosity	311 sec. @ 100° F.
Color	35 (in 6-inch cell)
Pour Point	5° F.
Vapor Pressure	0.015 mm @ 150° F.

Application of Unit Operations To Fractionation and Other Vaporization Processes

PART 8
Pressure Temperature Composition Relationships of Binary Mixtures

R. L. HUNTINGTON, School of Chemical Engineering, University of Oklahoma

A SOUND understanding of the principles underlying the behavior of various binary mixtures is essential for the engineer who expects to become proficient in the design of fractionation and distillation equipment. In the several previous papers of this series some of the elementary laws have been explained, as well as specific examples showing the application of these laws to field and plant practice.

In general, there are three types of binary mixtures to be considered, (1) mixtures in which the two components are miscible in all proportions, (2) mixtures in which the two components are totally immiscible, i.e. there is substantially no tendency for the one to mix or form a solution with the other, (3) mixtures which are miscible within certain ranges of composition but outside of these ranges form two phases, each phase being a definite mixture of the two components.

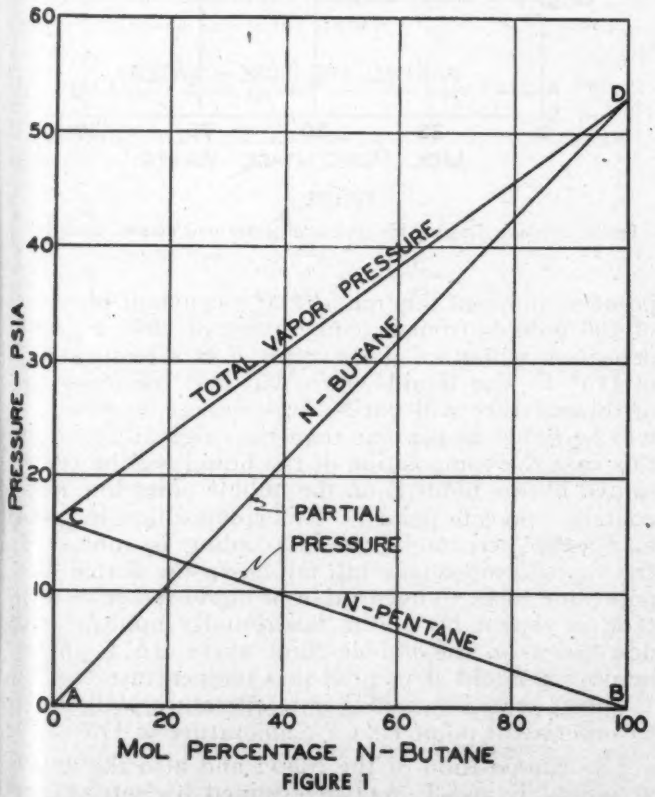


FIGURE 1

Graph showing relationship of partial pressures to mol fractions for normal butane-normal pentane mixtures. Temperature=100° F.

Miscible Mixtures

Pressure Composition Diagram—When two components are miscible in all proportions in the liquid phase, there is a tendency for the one having a higher vaper pressure to speed up the other which has a lower vapor pressure, and vice versa. Such a behavior might be compared to a team of horses, where a spirited horse might have a tendency to speed up the slower-moving member of the team. And likewise the slower member would tend to reduce the speed of the faster horse. When two liquid components behave in such a manner as described above, it is said that they perform according to Raoult's law.

Figure 1 is presented in order to picture this performance in terms of the partial pressures exerted by each compound in the liquid state. Referring to this diagram, it is seen that the partial pressure of butane varies from zero when all of the liquid consists of pentane, while its partial pressure is 53 pounds per square inch at 100° F. when all the liquid is normal butane. The partial pressure of the butane in intermediate mixtures is shown by line AD. Likewise, the line BC shows the partial pressures of the pentane between zero percentage up to 100 mol-percent pentane. The sum of the partial pressures is shown by line CD. In other words, a 50-50 mixture of the two components will exert a total vapor pressure half way between C and D, or $\frac{16+53}{2}$ which is equal to 34.5 pounds per square inch absolute. It is well to remember that this chart is based on one temperature which in this case is 100° F.

Another way of presenting the pressure-composition relationship is shown in Figure 2 in which the

three regions, gaseous, vapor-liquid, and liquid zones are shown. The line CED represents the boundary between liquid and the liquid-vapor zones. Or in other words, points along this line are called bubble points. The dotted line CFD is the boundary between the gaseous and the vapor-liquid regions. This

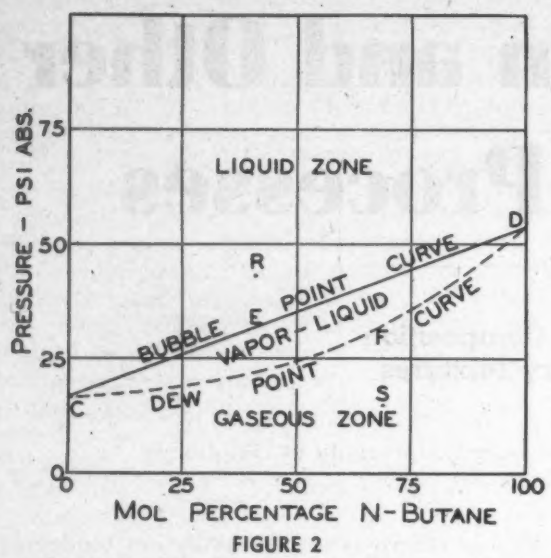


FIGURE 2

Pressure composition diagram showing liquid gases and vapor liquid regions for normal butane-normal pentane mixtures at 100° F.

line is known as the dew-point curve. If the pressure on a liquid at point R is lowered to location E, vaporization will occur, the first bubble of vapor being that of composition F horizontally opposite point E. If the pressure on the liquid is lowered still further, vaporization will continue to occur until all of the liquid is brought to point C, where total vaporization will have taken place. At the intervening points between E and C, the vapor composition in equilibrium with the liquid will fall on line FC at corresponding horizontal positions.

In the same way, if vapor at S is raised in pressure to location F condensation will begin to take place, the first drop of liquid being of Composition E. With further increase in pressure, the vapor will continue to condense, giving off liquid at points on line ED directly opposite the horizontal points on line FD.

Temperature-Composition Diagram—The relationship between the temperature and composition is shown in Figure 3 for a binary mixture of two miscible compounds. The envelope CD represents the enclosure of the liquid-vapor region while the area above is the gaseous region, and the area below, the region in which nothing but liquid can exist. This particular diagram has been made up for butane-pentane mixtures, all at 100 pounds per square inch, absolute. The point C indicates that a temperature of 220° F. is necessary for normal pentane to exert 100 pounds per square inch, while normal butane will exert the same pressure at 144° F. The line CED illustrates the bubble points of various mixtures between the two extremes of 100 percent pentane and 100 percent butane. The dotted line CFD shows the dew points for the same range of mixtures. If we take a mixture consisting of 71.2 percent butane as indicated by

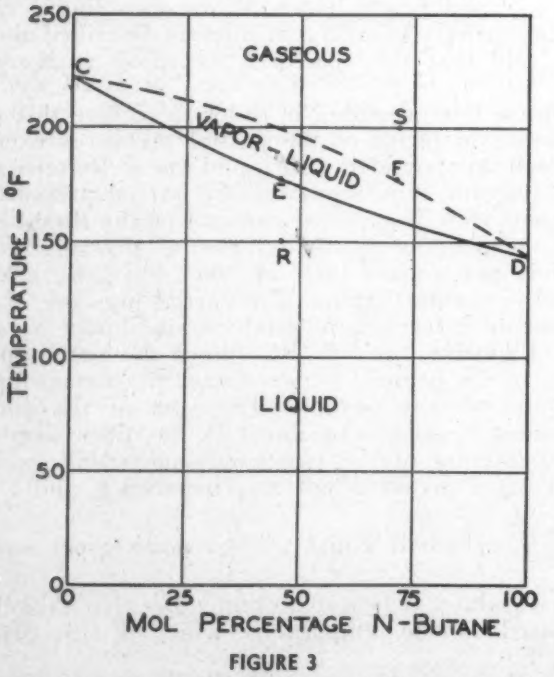


FIGURE 3

Temperature composition diagram for normal butane-normal pentane mixtures at 100 pounds per square inch absolute.

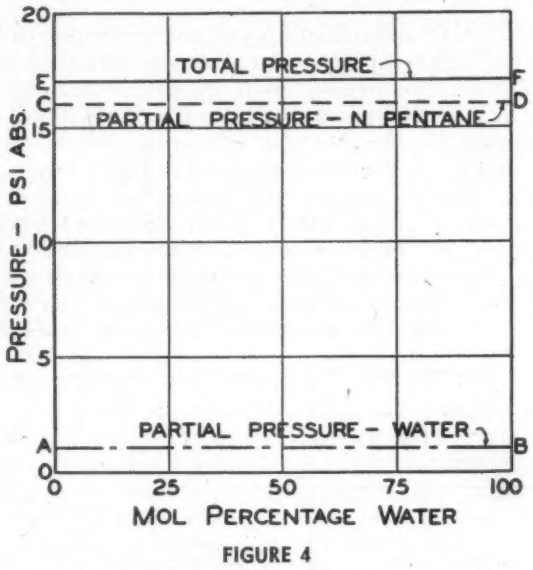


FIGURE 4

Partial pressure diagram for system of water and normal pentane.

point S, and cool this mixture at a constant pressure of 100 pounds from a temperature of 200° F., condensation will start at the point F at a temperature of 175° F. The liquid which will first condense out of this mixture will not be pure butane, however, it will be richer in pentane than the original vapor. In this case the composition of the liquid will be represented by the point E on the bubble point line horizontally opposite point F. This composition happens to be 48.5 percent butane. If cooling is continued, the vapor composition will fall down the dotted dew point line to D. Condensation of liquid richer in pentane is shown by points horizontally opposite the dew point on the bubble-point curve. In a similar manner, a liquid at point R at a temperature of 150° F. when heated to a higher temperature, will begin to vaporize at point E at a temperature of 175° F.

The composition of the liquid and also the vapor at points E and F was determined by setting the temperature at 175° F. (Pressure already set at 100 pounds.) From the phase rule, the system is fixed.

Applying Raoult's law:

$$\pi y = px \qquad x_4 + x_5 = 1$$
$$C_4\ 100y_4 = 150\,x_4 \qquad y_4 + y_5 = 1$$
$$C_5\ 100y_5 = 53\,x_5$$
$$y_4 = 71.2$$
$$x_4 = 48.5$$

Immiscible Liquids

1. Normal Pentane-Water System—Although the hydrocarbons and water are slightly soluble in each other, they are generally considered to be immiscible from a practical standpoint. In such cases each liquid component can exert its full vapor pressure independent of the other. In Figure 4 a pressure-mol composition diagram is shown for a system containing mixtures of normal pentane and water at a temperature of 100° F. The partial pressure of water is represented by line AB (0.95 pound per square inch absolute) and that of normal pentane by CD (16 pounds per square inch absolute). The total pressure line is EF (16.95 pounds pressure). From this diagram it is easily seen that the total vapor pressure is the sum of the two vapor pressures, regardless of the percentage of each constituent present in the liquid phase. The equilibrium vapor above any liquid mixture of normal pentane and water at 100° F. would be

$$\frac{16}{16.95} \times 100 = 94.3 \text{ mol percent normal pentane}$$

and

$$\frac{.95}{16.95} \times 100 = 5.70 \text{ mol percent water vapor}$$

2. Maximum and Minimum Boiling Point Mixtures—There are certain aqueous solutions which possess the peculiar property of boiling at a constant temperature and pressure, provided a definite percentage of each component is present. No doubt some hydrate or loose physico-chemical union is formed between the water and the solute.

Water and hydrochloric acid are miscible in all proportions, however, they do not behave like a mixture of hydrocarbons, in that a maximum boiling point is reached whenever a definite percentage of water is present in the solution. Figure 5 is a representative graph of the temperature-composition relationship for a binary system possessing such a maximum boiling point. For example, the bubble point curve ADC includes liquid compositions which give off vapor having corresponding horizontal positions on the dew point curve AEC. Likewise liquids at their bubble points along CFB would produce vapors having compositions on CGB. With rising temperature any liquid mixture would tend to approach the point C where the liquid and the vapor would be of the same composition.

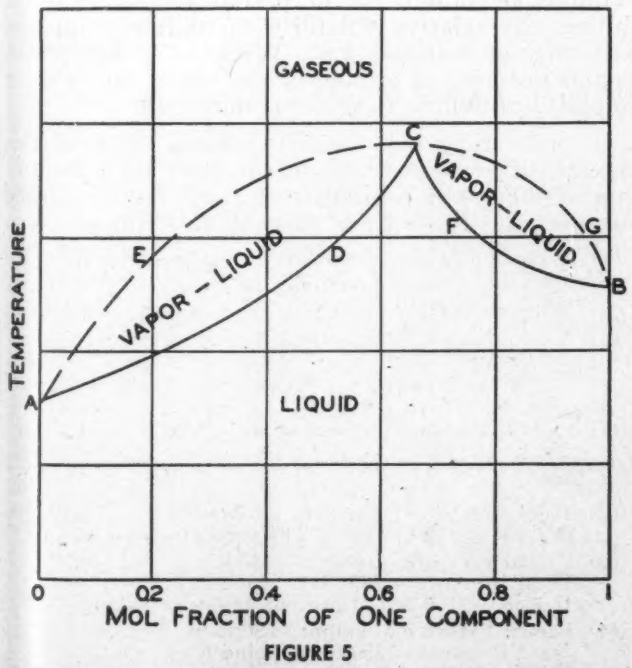


FIGURE 5

Temperature-Composition Diagram for a binary system having a maximum constant boiling point.

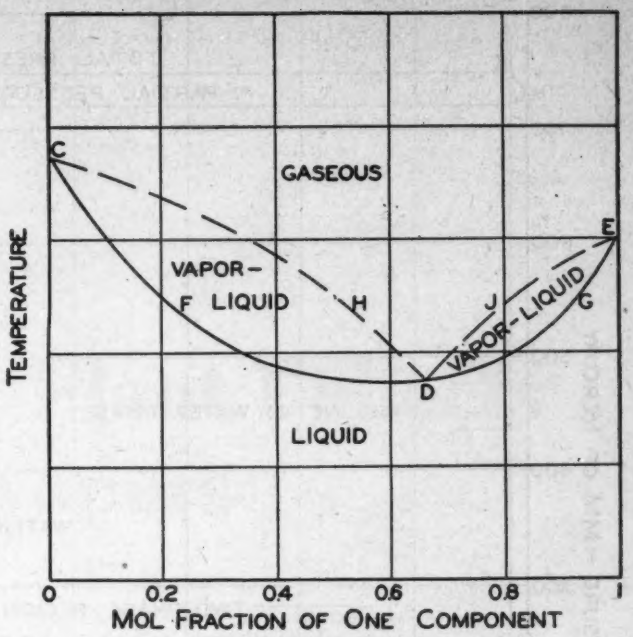


FIGURE 6

Temperature-Composition Diagram for a binary system having a minimum constant boiling point.

Ethanol and water which are miscible in all proportions form a minimum boiling point as shown in Figure 6. The bubble-point curve is designated by CFDGE, while the dew-point curves follow the dotted line CHDJE.

3. Binary Systems of Partial Miscibility—There are a number of binary systems in which the two components are miscible in each other over certain narrow ranges of composition. Outside of these two ranges the two components form two phases, each phase containing a certain percentage of one constituent dissolved in the other. For example the system (aniline and water) behaves according to this rule. A pressure-composition diagram of this system is shown in Figure 7 at a temperature of 99° C. At this temperature water saturated with aniline contains 1.42 mol-percent aniline, while aniline saturated with water contains 31.6 mol-percent water and 68.4 percent aniline. Any mixture containing aniline between 1.42 mol-percent and 68.4 mol-percent will form two liquid phases, one, the water phase saturated with aniline, and the other, the aniline phase saturated with water.

From the diagram, it is readily seen that Raoult's law is the governing factor in the behavior of aniline in the aniline phase, and for water in the water phase. When either constituent is present in a phase in small percentage, such as aniline in the water phase and water in the aniline phase, it is to be ob-

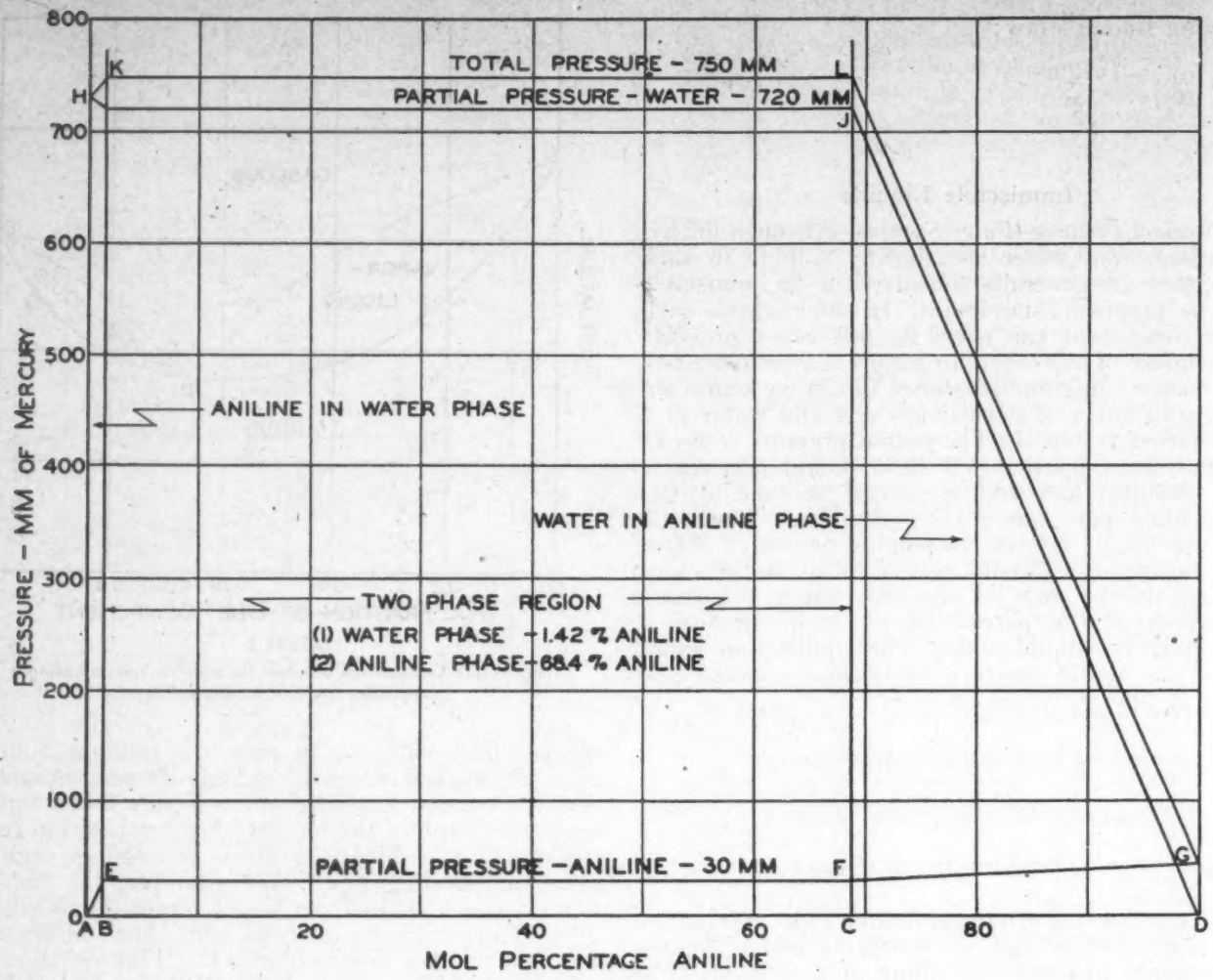


FIGURE 7

Pressure composition diagram for aniline-water system at 99° C.

served by lines AE and JD that the aniline and water behave respectively according to Henry's law where Y is equal to KX (Y and X are the mol fractions in the vapor and liquid respectively), K being determined experimentally. In these two particular cases, the constituent when present in small percentage, exerts a much higher relative volatility than it does when present in large percentage. For example, at point E on the partial pressure line for aniline, the relative volatility of aniline compared with that of water is 2.87. While at F where the partial pressure of aniline is the same, the relative volatility of aniline to water is only .019.

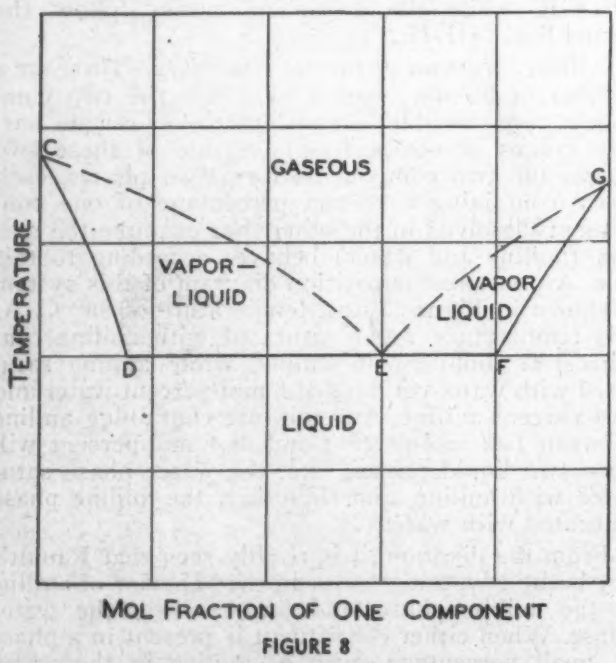


FIGURE 8

Temperature-Composition Diagram for a binary system of partial miscibility.

In order to gain a better understanding of this diagram it might be well to calculate the composition of the vapor coming from the following liquid mixtures:

(1) A liquid mixture containing 1 mol-percent aniline.
(2) A liquid mixture containing 85 mol-percent aniline.
(3) A liquid mixture containing 50 mol-percent aniline.
(4) A liquid mixture containing 20 mol-percent aniline.

Solutions:

(1) Partial Pressure of aniline $= \frac{1}{1.42} \times 30 = 21.2$ m.m.

(See Line AE)

(2) Total Pressure = 745 m.m. (Line HK)
$21.2/745 = .0284 \times 100 = 2.84$ percent aniline in vapor

(3) Partial Pressure of aniline = 37.3 m.m.
Total Pressure = 380 m.m. (Line LG)
$37.3/380 \times 100 = 9.83$ percent aniline in vapor

(4) Partial Pressure of aniline = 30 m.m.
Total Pressure = 750 m.m. (Line KL)
$30/750 \times 100 = 4.0$ percent aniline in vapor

(5) Same as part (4)

Temperature-Composition Diagram for a Binary System of Partial Miscibility

The relationship of vapor to liquid composition for different temperatures all at a constant pressure is shown in Figure 8. It is interesting to observe that any liquid between points D and F will give off vapor of composition E. Liquids along the bubble point line CD will give off vapors along CE at horizontal positions on the respective curves, and likewise liquids along FG will evolve equilibrium vapor leaner in the same component along the line EG.

In the next of this series, a discussion will be given of some of the simpler methods used in determining the number of theoretical trays required for the separation of binary mixtures of hydrocarbons.

Literature Cited

Huntington, R. L., Refiner and Natural Gasoline Manufacturer, series of papers "Elements of Vaporization and Condensation" beginning February, 1944.

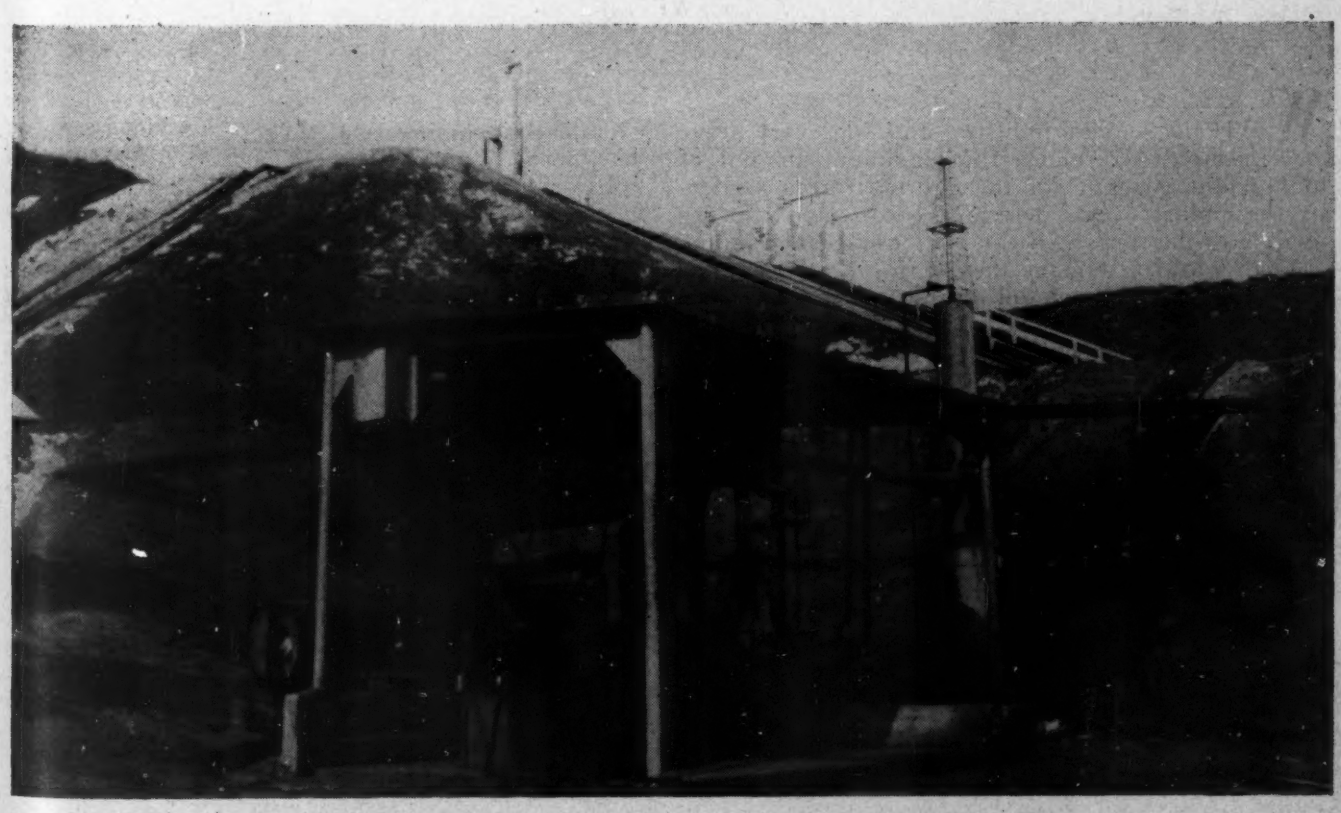
Lease Booster Plant Collects Tank Vapors

THROUGH a cooperative program between oil producers and gasoline-plant ownership, the Del Valle field in California has been provided with a series of small booster stations which remove all light vapors from lease storage. Each battery is provided with a self-contained gas-engine-compressor unit, which is semi-automatic in operation.

Each unit is built on a skid base. Each consists of a four-cylinder, water-cooled gas engine, which through V belts drives a double-acting single-cylinder compressor. Through a system of piping, pressure relief valves, vacuum breakers and suction-pressure regulators, vapors are removed as they come into the traps or as they are released from storage.

These installations recover the light hydrocarbons, which otherwise would be lost through relief valves on lease storage batteries or through escape from other producing equipment.

Water for cooling the units is piped to all leases and taps are provided at each booster with an adequate amount of cooling water, which is admitted to the cooling system periodically as the operators make infrequent visits to the installations. Water for engine cooling is contained in radiators that require addition only as evaporation takes place. A steel reservoir is installed above the machines, suspended by roof trusses, for thermo-syphon circulation through the jackets. These boxes have sufficient capacity for maintaining relatively low temperatures in the compressor, admitting hot water at one end and releasing cooled water at the opposite end. Travel throughout the length of the boxes is sufficient to reduce temperatures so that the jackets are never above efficient operating conditions.



Cooling water for the compressor is circulated through the radiator attched to the roof of the shed which protects the field unit. The upright vessel outside the housing is a separator to prevent liquids from entering the compressor.

To demonstrate that viscous oil would froth when water was applied, residuum was allowed to burn in a 52-gallon drum, and extinguished with a ¾-inch hose in 20 minutes. Frothing smothered the flame.

How to Organize And Conduct

A Refinery Fire School

J. C. WATKINS

WITH the refining industry straining every nerve and resource to produce the maximum amount of high-octane gasoline for the fighting forces, leaders in the industry are determined to combat every menace to the successful completion of that program.

Fire remains one of the prime threats to the security of the nation's oil output, and refining officials are redoubling their efforts to achieve maximum control over this hazard. Many plants are participating in the Petroleum Industry War Council's program for sponsoring fire laboratories at which men in the fields of production, refining and shipping may improve their fire-fighting skill and knowledge.

How to organize such a fire-fighting laboratory was interestingly demonstrated at Port Arthur recently. Sponsored by the Petroleum Industry War Council's Committee on the Protection of Petroleum Facilities, Gulf Coast Region, of which Frank L. Wallace, The Texas Company's Port Arthur works manager, is chairman, the fire school was conducted by the local oil companies with the cooperation of the United States Coast Guard Waterfront Protection Service.

In attendance were 352 representatives of 33 organizations, most of them from oil companies in the area from Corpus Christi, Texas, to Baton Rouge, Louisiana.

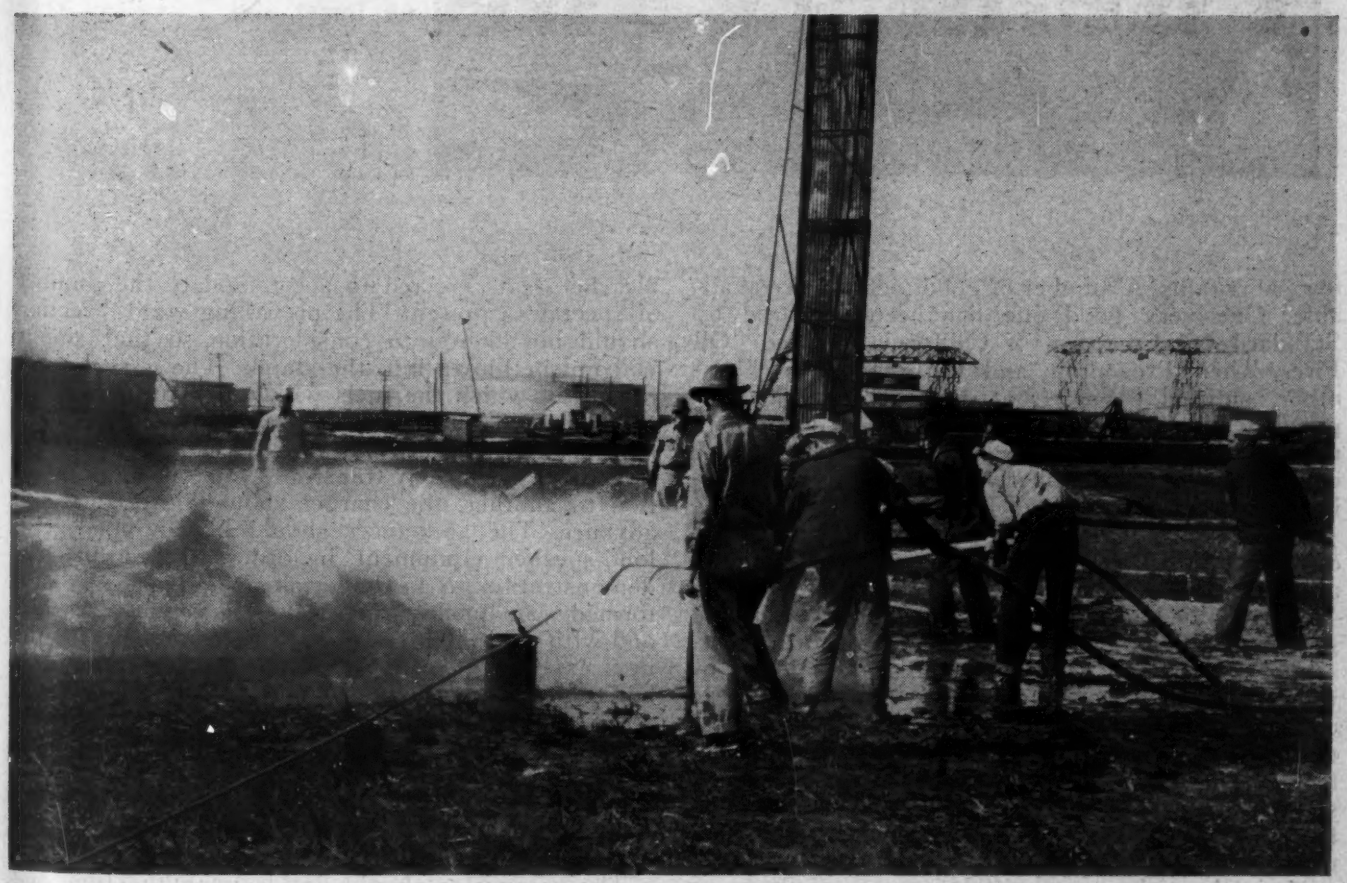
The fire school was organized and directed by a committee including F. M. Leverett, power engineer, The Texas Company; H. H. Tadlock, fire chief, Gulf Oil Corporation; R. P. Davies, assistant general operations foreman, The Pure Oil Company; H. H. Harding, Magnolia Petroleum Company; L. W. Evans, personnel director, The Atlantic Refining Company, and Lt. L. B. Wilson, United States Coast Guard.

It should be emphasized that to conduct a fire school successfully, it is necessary to have in charge a committee whose members have a thorough knowledge of the hazards involved in the oil industry as well as a thorough understanding of the uses for fire-fighting equipment. The following suggestions may be made as a result of the experience at the Port Arthur school.

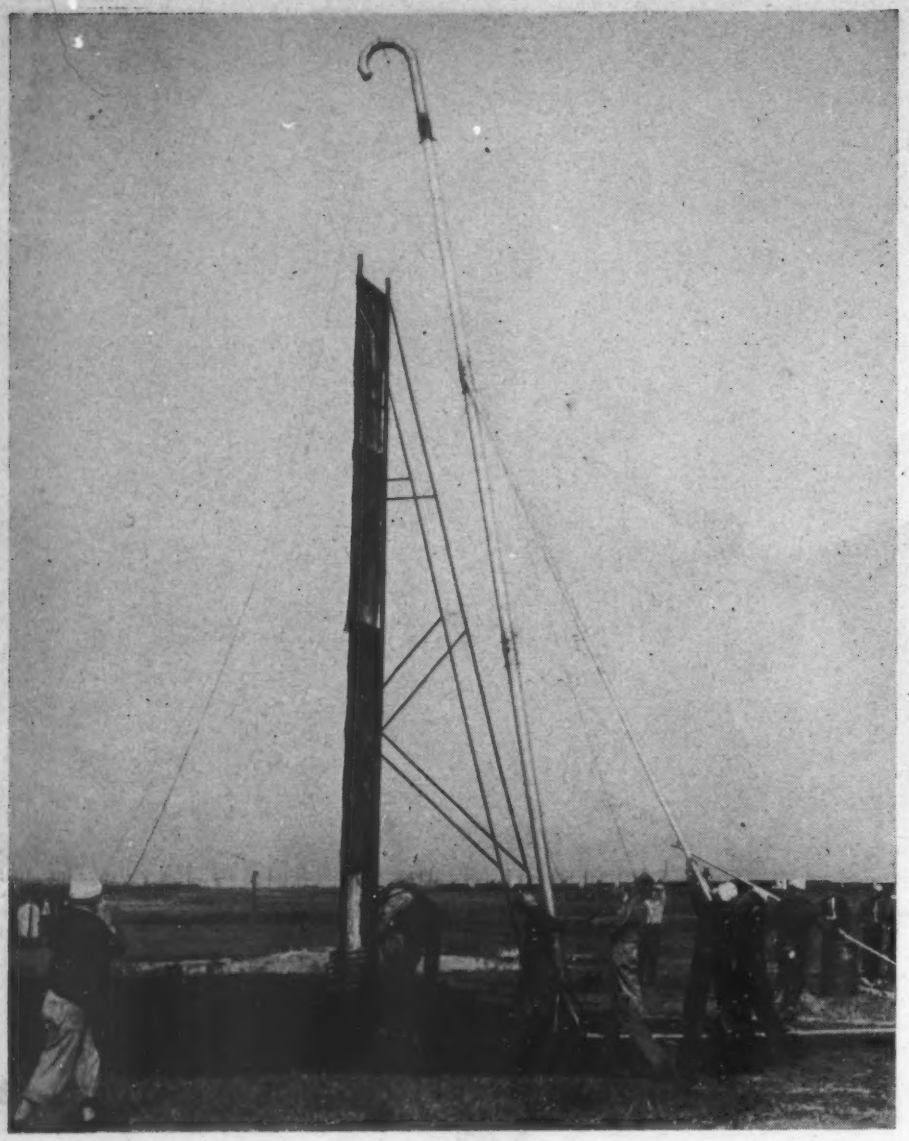
After selection of a committee, the next step is a suitable location. For the classroom session it is desirable to have a large room where motion pictures can be shown. For the field demonstrations an area sufficiently large to permit sizeable oil fires without endangering surrounding property is necessary. An adequate water supply should be available. A supply of steam and electric power is desirable but not necessary.

The committee in charge should arrange for the showing of suitable motion pictures together with a

Slop light oil with combustible material was burned in a pan 21 by 48 inches for 165 seconds, and was extinguished in 5 seconds with carbon dioxide and soda-acid extinguishers. Carbon dioxide was used to extinguish and soda-acid to cool the combustible material to prevent flash back.



After burning 25 seconds, flame from gasoline flowing through a ½-inch line with 30 pounds pressure was controlled but not extinguished in 75 seconds, using two 1½-inch low-velocity fog nozzles and one 2½-inch high-pressure fog nozzle. Two low-velocity nozzles first used caused the burning gasoline to spread, and when the high-velocity nozzle was brought into play the flame was controlled so that the valve could be closed.



How to fight a fire in an oil tank is illustrated here as a 40-foot portable foam tower is hoisted into position against a sheet metal barricade 32 feet tall, built to represent the side of an oil tank. The foam tower can be hoisted into position in two minutes by eight men. Foam started through the tower from a portable foam generator, comes out of the goose-neck and down the inner wall of the tank and spreads over the surface of the burning oil, smothering the fire. The foam tower is always erected on the lee side of the tank. A workman is shown pouring oil into the pit at the bottom of the barricade. This will be ignited to simulate an oil-tank fire.

few short talks. A number of good pictures are available. One very good one has been prepared by Standard Oil Company of California entitled "Oil Fires, Their Prevention and Extinguishment." Another, entitled "Waterfront Protection," was prepared by the United States Navy. There are others made up by various companies manufacturing fire equipment, the Fire Underwriters Laboratory, moving pictures of the Chicago Fire School, and the like.

Speakers should be chosen to explain the operation of the types of fire-fighting equipment usually found around an oil refinery.

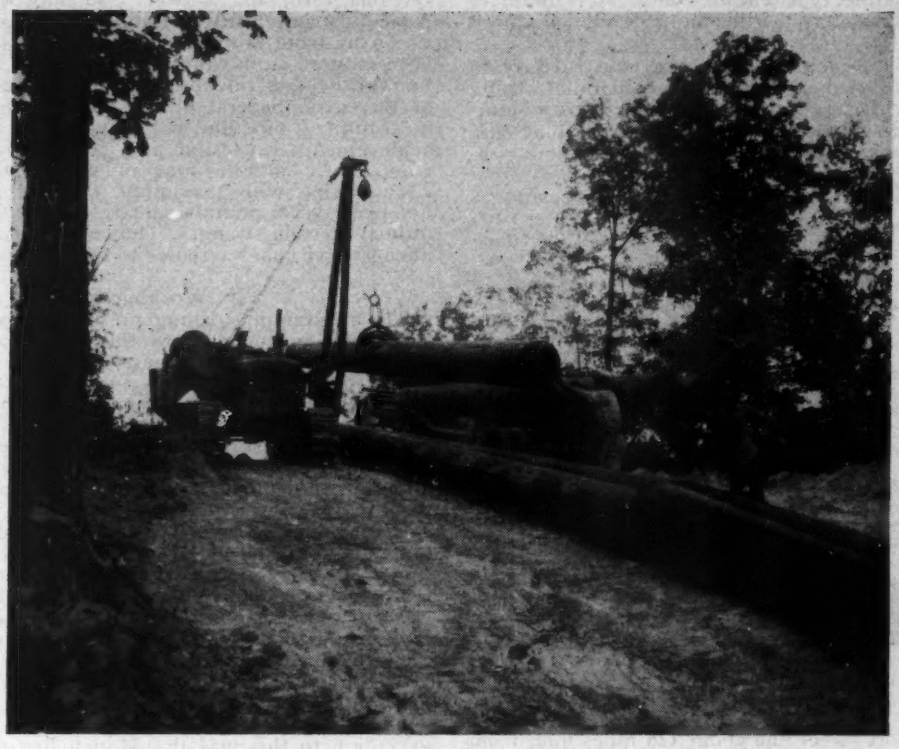
Those to be invited to the school should be selected so as to include a good number of the operating personnel who would actually be present at locations where fires may occur, and who would take part in combatting them, rather than confining the school to the supervisory staff who would not likely be on hand when fires begin. This is particularly desirable since it is estimated that 85 percent of all major conflagrations could have been prevented if the proper use of ordinary first-aid type of equipment had been made in the early stages of the fire.

One of the more important phases of the school is the field demonstrations. It is desirable to have bleacher seats erected to accommodate the number of spectators present. The prevailing wind direction should be taken into consideration so that smoke will not be blown into the stands. The various containers in which the fuels will be ignited should be established a sufficient distance apart so that the flames will not leap from one vessel to another.

To facilitate speedy transition from one demonstration to another, the charges should be prepared in advance. The announcer should be equipped with loud-speaker equipment in order to describe the demonstration to be undertaken, and as it is performed, can quickly report the timekeepers' results and with a minimum of elapsed time can describe the next experiment on the program. Likewise the crew and supervisor can move quickly from one demonstration to another.

Incidentally, representatives of companies manufacturing fire-fighting equipment were not permitted to demonstrate their products at the Port Arthur school, although some of them were present for the demonstrations.

The committee should decide upon the type and nature of fires for use in the field demonstrations, together with the fire-fighting methods to be used.



Twenty-four-inch welded pipe and maximum pressure of 750 pounds, as used in Tennessee Gas & Transmission Company's line from the Southwest to the East, is typical of the trend in

Gas Transmission Practice

LORING E. HECKMAN,
Consultant, Natural Gas-Natural Gasoline Division,
Petroleum Administration for War

OVER 83 percent of the known available natural gas reserves in the United States are concentrated in an area including Louisiana and Texas and seven counties in Western Kansas and Oklahoma. Long pipe lines transport gas produced in this area to such distant centers as Denver, Minneapolis, St. Paul, Kansas City, St. Louis, Chicago, Detroit, Memphis, Birmingham and Atlanta. The growth of natural-gas consumption in most of these centers is taxing the capacity of existing lines to the limit, with the result that further looping of these lines is expected in the near future.

A large portion of the natural-gas consumption of areas such as the Appalachian area, the Eastern Kansas-Oklahoma area, and California has been supplied by local production. However, as a result of very high demands upon these local sources during the last four years, there has been a rapid decline in reserves and deliverability, and there is now a need for new transmission lines to carry gas from concentrated supply areas to these established markets to compensate for declining local production.

In view of the necessity for additional natural-gas transmission lines in the near future, the practice in design and construction of the lines which have been built recently, or are in the process of construction, should be examined to emphasize those factors which tend to minimize the cost of transmission.

In the design of a gas transmission line, selection of the size of pipe, the number of compressor stations and the ratio of compression are determined by equations of gas flow and factors of cost along established principles which have been amply discussed in the literature of the gas industry. It is in the selection of materials and of operating pressure that modern practice indicates trends to lower cost.

Certain phases of gas-transmission-line practice have undergone a change as a result of improvements in pipe welding, in pipe manufacture, in pipe coating and cathodic protection methods, in high-pressure valve manufacture, in engine-compressor units and in the technology with reference to super-compressibility and pipe-line-friction factors. While some of the modern types of material have been available for a considerable time, it has taken the test of time and use to prove the material and its application. Take the case of high-grade electric weld and seamless pipe. This material has been available since about 1931. Yet, until recently, it was not thought practical to employ pressures which would stress the pipe to 70 percent of yield strength, which is equivalent to a safety factor of 1.4 to 1.5. The apparent delay in the full use of new methods and materials is due largely to the fact that 1931 marked completion of a great expansion of natural-gas lines and no large transmission lines have been built until recently, with the exception of the looping programs of existing lines. In some cases, thinner-walled pipe was used than had been installed on the lines which were being looped, but the operating pressures were limited by the original lines.

The tendency at the present time is to employ working pressures of from 700 to 800 pounds on long lines and higher

pressures on short lines where field compression is not necessary, to determine safety factors on the basis of the yield strength of the steel rather than the ultimate tensile strength, to install angle type engine-compressor units, to dehydrate gas before it enters the line and to establish a high sustained load.

In 1891, two parallel 8-inch gas lines were constructed into Chicago from Greenstown, a distance of 120 miles, using wrought iron pipe with screw joints. The maximum operating pressure was 525 pounds,[1] which was unusual at that time. In 1909, Cincinnati Gas Transportation Company constructed a 20-inch "soft" steel line about 126 miles long from Kenova, West Virginia, to Cincinnati, Ohio, using couplings. This line had a maximum operating pressure of 325 pounds. Many other lines of similar length and capacity were constructed up to 1926, most all of them being limited to about 300 pounds maximum working pressure, some using wrought iron pipe, but many with lap-welded steel pipe of about 45,000 pounds tensile strength.

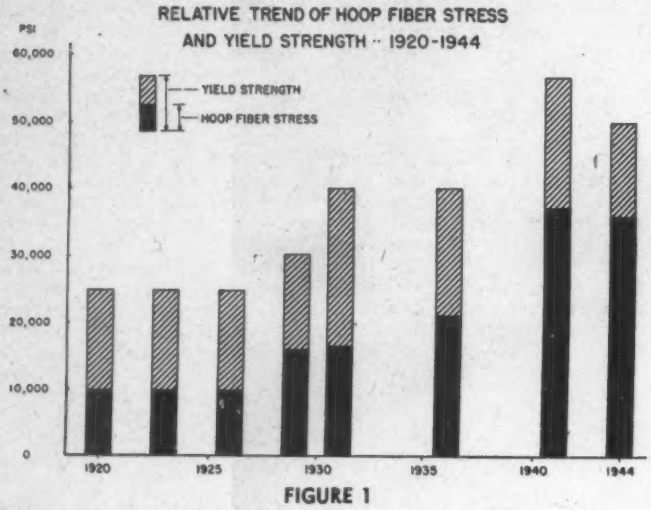


FIGURE 1

The construction of Interstate Natural Gas Company's 170-mile, 22-inch steel pipe line from Monroe to Baton Rouge, Louisiana, in 1926, and its 90-mile extension of 18-inch in 1927 marked the start of the expansion of long gas lines which took place up until the end of 1931. Pacific Gas & Electric Company's 16- and 22-inch line from Buttonwillow to Milpitas, California, completed in 1929, was the first large gas line of all-welded construction. The Standard Oil Pacific Gas transmission line from Buttonwillow to Oakland, California, was the first major long natural gas line to use 26-inch pipe.

Table 1 shows 16 natural-gas transmission lines constructed from 1926 to date. While some 40 transmission line projects have been considered in reference to this subject, those listed have been chosen in general because they are major projects or are significant of the trend of transmission-line practice. The transmission lines of Cities Service Gas Company from Pampa to Wichita, Colorado Interstate Gas Company from Texas to Denver, the Columbia Gas & Electric Corporation from Boldman, Kentucky, to Coatesville, Pennsylvania, Montana Power Company from Cut Bank to Anaconda and Butte, Montana, and Southern Natural Gas Company from Monroe, Louisiana, to Atlanta, Georgia, have been omitted from the table because of lack of full information on the wall thickness of the pipe and the characteristics of the steel. Several of these lines undoubtedly mark the most difficult pipe-line work undertaken and they are distinct achievements in design and construction. These lines are from 200 to 450 miles long and consist mostly of 20-inch and 22-inch pipe with maximum working pressures which do not exceed 500 pounds, and safety factors of 4 to 5 on the ultimate tensile strength. Thus it can be seen that these lines have similar characteristics to those listed on the table.

Working Pressure

The maximum working pressure cannot actually be considered as independent of the safety factor. With a given line size, pipe-wall thickness and yield strength, the safety factor decreases with the increase in maximum working pressure. The principal point to be emphasized is that operators now have sufficient confidence in material standards and construction work to be willing to operate lines at maximum working pressures which will stress the steel in the pipe to about 70 percent of the yield strength, or in other words, to use a safety factor of 1.4 to 1.5.

The conditions which influence the determination of the maximum working pressure should be considered. The selection of the maximum working pressure employed in a transmission line is largely dependent upon the engineering judgment of those responsible for the operation and is a question of how much reliability should be placed on materials and construction methods.

The maximum working pressure on most major transmission lines constructed from 1926 to 1931 was limited to about 500 pounds as shown in Table 1. The outstanding exception to this was the 24-inch line of Natural Gas Pipe Line Company of America from the Panhandle field in Texas to Chicago, which was operated at 600 pounds initially and now operates at a maximum pressure of 712 pounds.

During this period, experience gained in the manufacture of large electric-weld and seamless pipe and in the construction and operation of hundreds of miles of gas lines under widely varying conditions, brought about improvements in design, in construction and in testing procedure. Lap-weld pipe began to be displaced with electric weld and seamless pipe. The use of couplings for all pipe joints was being replaced by composite weld and coupled lines and in some cases by all-welded lines. The technique of acetylene welding was introduced and improved. Similarly, arc welding was introduced and improved. Valves of suitable sizes which have been limited to about 500 pounds working pressure were modified and the working pressures increased. Leakage which was a major problem on screw lines of an earlier day was reduced to lesser importance in coupled lines by the use of improved coupling gaskets and was largely eliminated in all-welded lines.

As a result of this development, a change in construction practice began to be evident as illustrated by the 800- and 650-pound working pressures of El Paso Natural Gas Com-

TABLE 1

Natural Gas Transmission Line Characteristics 1926 to 1944

COMPANY	Date	Pipe Diameter—Inches	Length of Line—Miles	Pipe Wall Thickness—Inch	Max. Working Pressure, psi	Safety Factor Ultimate
Interstate Natural Gas	1926	22	172	5/16	350	4 to 5
Memphis Natural Gas	1928	18	210	1/4, 11/32	400	4 to 5
Pacific Gas & Electric	1929	16, 20, 22	297	1/4, 11/32, 3/8	400	4 to 5
Mississippi River Fuel	1929	22	431	1/4, 11/32, 5/16	400	4 to 5
*Standard Oil—Pacific Gas	1930	20 to 26	198	5/16, 11/32	400	4 to 5
Panhandle Eastern Pipe Line	1931	20, 22, 24	860	1/4, 11/32	500	4 to 5
Northern Natural Gas	1931	16 to 26	820	.....	400–450	4 to 5†
Natural Gas Pipe Line	1931	24	1000	1/4, 11/32	600‡	3.⊕
Hope Natural Gas	1936	12¾	93	1/4, 5/16	1300	3. Yield Point
Northern Natural Gas	1939	16	243	1/4	600	2.2
Natural Gas Pipe Line	1941	26	400	1/4	712	1.5
Southern Natural Gas	1942	14	120	1/4	1200	1.8
Oklahoma Natural Gas	1942	12¾	96	.259, 11/32, 1/4	1000	2.2
New York State Natural Gas	1944	12¾	145	11/32, 1/4	1000	2.2
Tennessee Gas & Transmission	1944	24	1200	1/4, 11/32	750	1.4
Cities Service Trans. & Chem.	1944	26	240	1/4	760	1.4

* Now an oil line. † The safety factor of several sections is not known. ‡ "Transportation of Natural Gas from Texas to Chicago". W. Soc. of E. J. 40:54-58 Ap '35. ⊕ Based on an assumed tensile strength of 80,000 per square inch and 1/4-inch pipe.

The safety factors listed have been calculated on Barlow's formula using the pipe-wall thickness for the section or sections having the maximum working pressures. The figures 4 to 5 have been used because available data is not sufficiently accurate to warrant a closer figure. The company names listed are the present owners of the lines and not necessarily the original builders.

pany's extensions to Bisbee and Douglas and to Phoenix, constructed in 1931 and 1933, and the Zionsville to Detroit extension of Panhandle Eastern Pipe Line in 1936 having a 600-pound working pressure. In 1936, Hope Natural Gas Company completed a 12¾-inch line 93 miles long in West Virginia, from Cornwall Compressor Station to Hastings Station, designed to operate at 1300 pounds. The use of such a high working pressure is a land mark.

In 1941, United Gas Pipe Line Company built a 200-mile line from Lirette, Louisiana, to Mobile, Alabama, with a maximum working pressure of 1000 pounds,[2] since high-pressure gas was available at this field.

In 1942, Southern Natural Gas Company and Oklahoma Natural Gas Company each built solid welded lines from high-pressure fields with 1200 and 1000 pounds working pressure, respectively. Southern Counties Gas Company is building a line in California between LaGoleta storage field and Los Angeles, of which 36 miles will have a maximum working pressure of 1000 pounds. These lines illustrate that working pressures of 1000 to 1200 pounds are feasible with the present method of construction, and practical where such pressures are available without compression. This is particularly significant in relation to the 22 trillion cubic foot reserve[3] of the condensate fields located in Texas and Louisiana, where the rock pressure is very high. While the pressures at which this gas will be available to pipe lines will vary and cannot be stated exactly, pressures in excess of 1000 pounds will be generally available.

Selection of the maximum working pressure of a transmission line is partially dependent upon the field pressure and the length of the line. If sufficiently high field pressure exists to transmit a suitable volume of gas from a field through a pipe line to the market, without recompression, then this field pressure may well be the most economic maximum working pressure. If, however, the terminal point of the line is many hundreds of miles from the field and numerous recompressions are necessary, then it may not be economically sound to build the entire line for a high maximum working pressure.

The trend of modern practice is illustrated by three major transmission lines, one built, one building and one which was planned but not built, designed for working pressures of from 700 to 800 pounds. These are Cities Service Transmission and Chemical Company's 26-inch line from Hugoton field, which was designed to operate at 760 pounds working pressure; Tennessee Gas & Transmission Company's 24-inch line from Texas to West Virginia with 750 pounds maximum working pressures, and the line which Hope Natural Gas Company had contemplated building from Hugoton with an operating pressure of 770 pounds. These lines indicate the present practice of long natural gas transmission to use large diameter, thin-walled, high strength pipe with a maximum working pressure of from 700 to 800 pounds.

Safety Factor

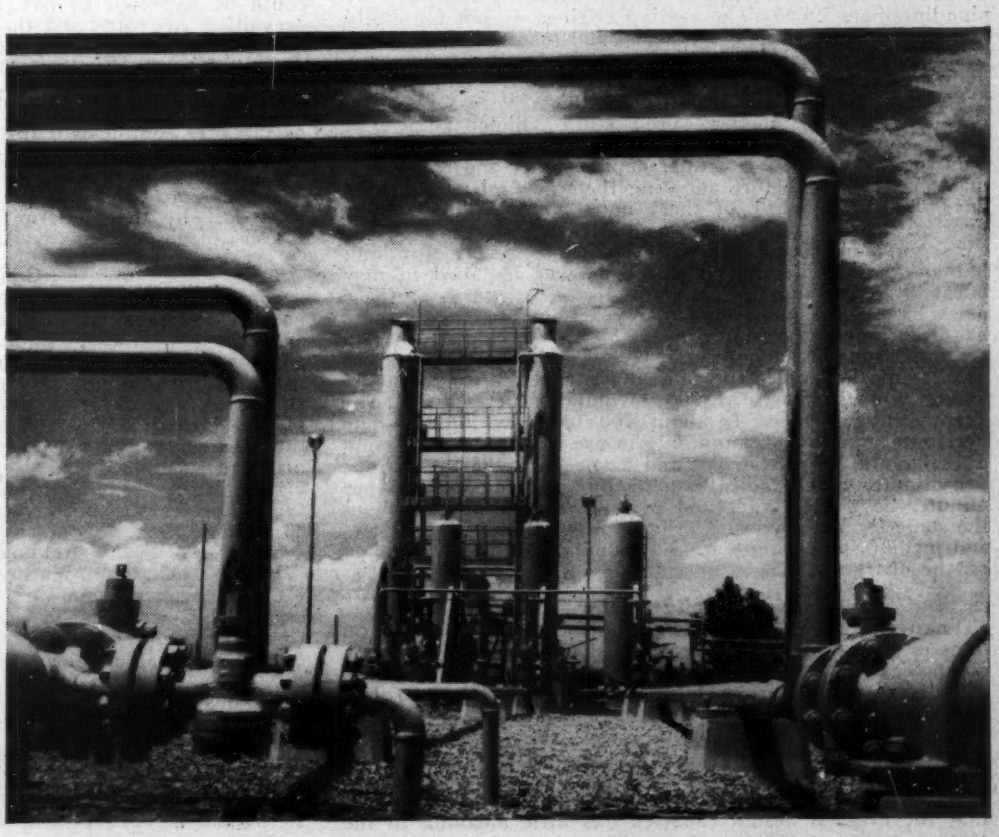
Table 1 shows that up to 1931, most pipe lines were designed with a safety factor of from 4 to 5 based upon the ultimate tensile strength of the pipe material. Up to about 1927, only butt-weld and lap-weld pipe were available. The lap-welded pipe had a tensile strength of about 45,000 pounds, with lap-weld joint efficiency of about 92 percent. The first electric-weld pipe was made in 1927. To meet this competition, other pipe companies undertook the manufacture of seamless pipe.

At the same time, another development was taking place in the field. In 1927, acetylene welding of joints was coming more into use. During 1929, arc welding was used extensively on gas transmission lines. In 1930, the shielded-arc electrode was brought into use, with the result that the welds were more ductile, hence safer. Most lines were still being built by welding several sections of pipe and then jointing these longer sections with couplings. This resulted in a flexible line able to provide for expansion and contraction caused by temperature changes.

Up to 1931, long gas lines of large pipe had been a new undertaking. There was no adequate background of experience in laying the pipe, in welding, in the use of couplings and in testing the lines. Also, mill standards were not as high as they later became. A certain tendency still existed to provide extra thickness in pipe walls for corrosion. Taken all together, the art was new and so it was considered good engineering judgment to provide a safety factor of 4 to 5 on the ultimate tensile strength of the steel. Actually, this was a safety factor of 2.5 to 3.0 on the yield strength of the steel.

In 1936, Hope Natural Gas Company built an all-welded line designed with a safety factor of 3 on ultimate tensile strength. In 1939, Northern Natural Gas Company extended its system 243 miles with 16-inch pipe with about the same safety factor. However, this line was designed for a safety factor of 2.2 on yield strength, and is believed to be one of the first natural gas transmission lines whose safety factor was based on the yield strength.

As illustrated in Table 1, gas transmission lines constructed from this time on were designed with a safety factor based upon the yield strength. Uncertainty about welding, non-uniformity of thickness of the pipe and erratic physical characteristics of steel in the pipe had largely disappeared. The 26-inch line of Cities Service Transportation & Chemical Company was designed with a safety factor of



High-pressure solid type adsorbent gas dehydration plant, Oklahoma Natural Gas Company.

1.4. The 24-inch Tennessee Gas & Transmission line, which is now being built, has a safety factor of 1.4. The 22-inch line, which Hope Natural Gas Company had proposed to construct in 1944, was designed on a safety factor of 1.4.

Use of safety factors of 1.4 to 1.5 on the yield strength shows complete confidence in the welding methods, in the pipe strength and uniformity and in construction methods. This practice has been made possible because the procedure of carefully inspecting and testing materials and workmanship of every mile of line has become a part of modern construction methods. The pipe manufacturers' guarantee of a specified yield strength is as reliable as their inspection and testing procedure. Sampling and testing of each welder's work before permitting him to weld joints on a pipe line helps to assure uniform welding. The hydrostatic test of completed sections of the line at pressures reasonably above the maximum working pressure and below the yield strength, eliminates faulty materials and workmanship. These testing procedures make it possible to design on the basis of a maximum working pressure equivalent to about 70 percent of yield strength.

Figure 1 shows the relative trend of hoop fiber stress and yield strength on typical gas lines constructed from 1920 to date. It illustrates that the yield strength has risen from 25,000 pounds per square inch in 1920-1928 to 50,000-55,000 pounds. This is an increase of about 120 percent. During the same period, the fiber stress increased from 1,000 to 36,000 pounds, or about 260 percent. While only a few examples have been illustrated on this chart, they are representative of the trend in fiber stress as compared with the trend in yield strength. This shows that transmission line practices have advanced to a point where much more efficient use is now being made of the strength of the pipe.

When welding of gas lines first begun, there was considerable objection to a solidly welded line without couplings or joints to provide for expansion. It was believed that longitudinal stresses resulting from the expansion and contraction due to temperature variation would cause the pipe to fail. The first large all-welded lines were constructed in California and in Texas, in locations where the temperature change was small. However, construction of Hope Natural Gas Company's line in 1936 with solidly welded construction helped dispell this fear and all-welded construction has now become accepted practice.

Compressors

Until about 1940, horizontal slow-speed gas engines were used almost universally as prime movers in gas booster stations on long transmission lines. The simplicity and reliability of the horizontal unit had proved itself in over 40 years of use. It warranted the confidence placed in it by pipe-line men. These slow-moving engines do not fail easily or quickly, and if carefully checked and repaired, their maintenance cost is reasonable. However, in the last four years, many medium speed multi-cylinder angle-type engine-compressor units have been installed for this service.

When the new medium-speed multi-cylinder angle-type engine-compressor units were brought out in 1937, the gas industry awaited proof of their dependability and reasonable maintenance cost before adopting their general use on long lines. However, many of these units were installed in refineries, gasoline plants and cycling plants. Since 1942, the gas companies have found it difficult to secure anything but an angle unit, and so this type was installed in new booster stations or station additions. Now many of these units have been pumping three years or longer, so there has been ample opportunity to establish their reliability and reasonable maintenance cost.

Most of the angle-type units have a stroke of about 14 inches. On the basis of 300 revolutions per minute, the average piston speed is about 700 feet per minute. The horizontal units most commonly in use on long transmission lines have a 36-inch stroke and a speed of 125 revolutions per minute, which indicates a piston speed of 750 feet per minute. So the cylinder and piston wear should be about the same for both types. The ignition systems of both slow- and medium-speed units are very similar, both having taken on the characteristics of an automobile-engine ignition.

Capacity Factor

The term "capacity factor" as applied to gas transmission lines is the ratio of the average load to the capacity. Many companies having closely interconnected networks of lines cannot determine the capacity of their systems and so they do not know the capacity factor. The various sections of such systems have been built over a period of years with different working pressures, lengths and sizes of pipe. As a result of changes in field pressure, and the growth or decline of loads, operating conditions have changed to the extent that the original design capacity has little meaning in the system network. In this type of system, the criterion of operation in lieu of a capacity factor is the load factor, or the ratio of the average load to the maximum load.

It is not economically feasible to construct a long line unless a high capacity factor can be assured, because of the large investment required and the high fixed charges resulting. There are several ways of establishing a high capacity factor, including the sale of gas on an off-peak basis and the use of underground storage reservoirs. When a new line is contemplated, contracts offered to distributing companies and to industrial concerns can be arranged to provide lower rates for gas sold during off-peak periods and thus offer an incentive for off-peak load. The large industries will purchase gas on this basis, provided the gas rate will compete favorably with other available fuel and will allow a margin for the cost of installation of necessary standby fuel facilities.

There has been an increasing use of old gas fields as storage reservoirs. Gas is injected into these fields during periods of low demand and taken out during periods of high demand, thus cushioning the effect of variations in demand. It is becoming the practice to use such fields when available to help develop the high capacity factor necessary for new pipe lines.

The capacity factor of most long gas lines constructed in the period from 1926-1931 was 60 to 70 percent at the time the lines were built. Now, most new lines have a capacity factor of about 80 percent.

The new lines of Cities Service Transportation and Chemical Company and Tennessee Gas and Transmission Company have been planned on the basis of high capacity factors. The large base load of the Cities Service system will provide a high sustained load for the Hugoton line. The large storage capacity of the Appalachian area will help to establish a high capacity factor on the Tennessee Gas and Transmission line. The existing partially depleted fields of this area will be called upon for much of the peak demand. Other new lines from concentrated production areas to the large markets are expected to have high capacity factors because of the necessity of carrying a great volume of gas long distances, economically.

The idea has recently been advanced that natural gas should be conserved for "higher" uses, such as domestic consumption, and that it is not to the best interests of such consumers that gas be sold at low-offpeak rates for boiler fuel. The problem of the transmission of natural gas from distant fields is largely a question of cost. As has been stated, it is not economically feasible to construct new lines unless they have a high capacity factor. It would be perfectly sound to build a line for a low capacity factor if consumers could be expected to pay a sufficiently high rate. Under prevailing gas rates and the present field cost of gas, it is not practical to build new lines with much less than 80 percent capacity factor. As the load factor of most gas distribution centers, which might be terminal points of long transmission lines, is much lower than 80 percent, provision must be made to complement this load. When the sale of gas on an off-peak basis will help to establish the capacity factor at the point where the construction of a new line is feasible, such sale is to the interest of the domestic consumer because it is only by the construction of such a line that distant sources of gas become available.

Conclusion

The art of transmitting the large volumes of natural gas has changed from an initial stage in the period from 1926-31 during which suitable high-strength pipe was being developed and methods of construction were changing, to the present period in which improved materials are available, workmanship is of high caliber and the maximum use is being made of pipe strength. The trends to minimum cost during this time are characterized by the use of maximum working pressures which will stress pipe to about 70 percent of the yield strength, by the installation of medium-speed angle-type compressing units and by capacity factors of at least 80 percent.

Acknowledgement

I thank Oklahoma Natural Gas Company and Tennessee Gas and Transmission Company for the use of the pictures exhibited, and Cities Service Transportation and Chemical Company and the Tennessee Gas and Transmission Company for valuable information furnished.

[1] "The Long Distance Transmission of Gas," H. C. Cooper, presented at World Fuel Conference held in London, England, 1928.

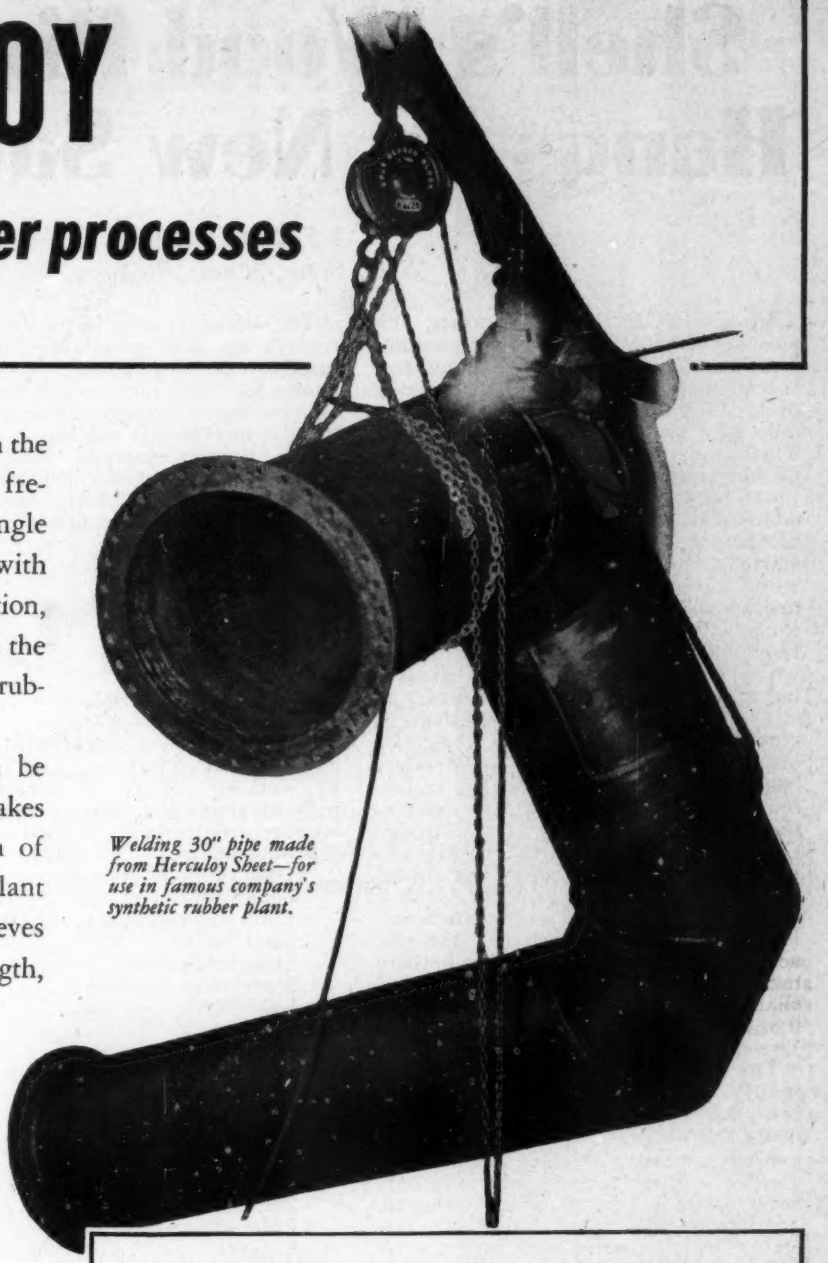
[2] "Constructing the Lirette-Mobile Line," W. B. Poor, Mech. Eng. 65:9-13Ja-'43.

[3] "Natural Gas Cycling and Its Significance to the Natural Gas Industry," Robt. W. Ducker and Frank H. Dotterweich, presented to the Natural Gas Section, American Gas Association, French Lick, Indiana, May 11, 1944.

[4] "Longest Welded Pipe Line," Gas Age Record 58:844 Dec. 11, 1926.

HERCULOY

in synthetic rubber processes



Welding 30" pipe made from Herculoy Sheet—for use in famous company's synthetic rubber plant.

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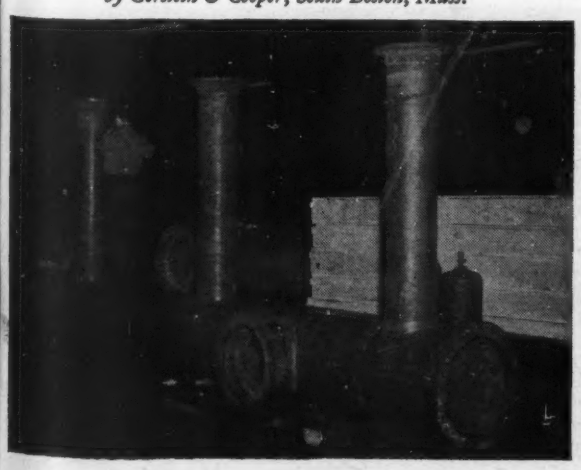
Manifold, 20" with 12" branches, fabricated from Herculoy Sheet by Gerstein & Cooper, South Boston, Mass.



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Shell's Wood River Refinery Hangs Up New Safety Records

J. F. GOLDSBERRY, Chief Engineer
Wood River, Illinois, Refinery, Shell Oil Company

ALTHOUGH the Wood River, Illinois, refinery of Shell Oil Company has been greatly expanded and many new special units added since the beginning of the war, the safety record has not only kept pace but has been improved. This is all the more significant in view of: longer work week and frequent overtime due to manpower shortage; the addition of many hundreds of new employees, some of whom are women, who started with little knowledge of the work required; the use of older tools in maintenance and frequent substitution for critical materials, and the usual wartime conditions such as distraction, worry, speed, and necessity of producing maximum amounts of products.

The refinery safety department is composed of a staff safety chairman, head safety engineer and seven safety inspectors. This organization, in collaboration with other departments, assumes the responsibility for all safety instructions and safe working conditions throughout the plant. Safety has always been stressed in the plant and a low accident-frequency record maintained. However, at the beginning of the war when considerable construction activity had already started and accidents were on the increase, it became evident that more activity in safety work was necessary if accidents were to be held in line.

The safety organization started an intensive drive to make everyone safety conscious, with a firm belief that accidents need not happen in spite of the unusual conditions being experienced. As a result, the safety record has not only been maintained but actually improved. This refinery is now one of the few plants in the petroleum industry in which the accident frequency has been lowered since the start of the war. In this period the refinery safety record has been exceeded twice and a total of 3,205,000 man-hours worked with one disabling injury. It may be added that the records are in no way influenced by injured workers returning to what is known as "light duty" to avoid disabling injuries, as the refinery physician's judgment is final in this respect.

The present average accident frequency for the refining industry as reported by the United States Department of Labor is 11.8. In comparison, this refinery's frequency record over the past 5½ years, including July, 1944, is as follows:

1939	2.51
1940	1.50
1941	3.75
1942	3.39
1943	2.89
1944 (7 mos.)	1.77

There are many departments which have hung up impressive safety records by working periods of several years without a single disabling injury: (The number denotes years worked since last disabling injury.)

Tool room attendants	20
Cooling-water system	20
Lube treating heavy oils	18
Blacksmiths	18
Shop machinists	18
Storehouse attendants	17
Laboratory	16
Lead burners	12
Slop recovery	10
Surveyors	9
Switching	9
Loading and Unloading	9
Lubricating Laboratory	9
Gas plant	8
Coke disposal	8
Brickmasons	7
Lube vacuum stills	7
Riggers	7
Lube dewaxing	6
Lube filters	6
Electricians	6
Cranemen	4
Welders	3

These safety records are attributed to constantly teaching safety thinking and a religious application of safe working methods. Safety thinking and safe practices become a matter of salesmanship which, when accepted by the employes, require only normal effort to continue. Supervision must first become interested and sold on safety, as experience has taught that unless safety thinking starts from the top, full benefits will not be reached on the way down. To accomplish this the old maxim "to increase interest, give a person something to do" was employed. Accordingly, all supervisors were given an opportunity to lead meetings. In this manner it was soon discovered that there was an abundance of latent safety leadership which had never taken special interest in safety work. It was also found that this interest increased the more they became involved in the work.

Approximately 50 safety meetings are held each month. All maintenance and construction employes attend meetings of one hour's duration. In some departments where it is more convenient, small group sessions are held weekly. All employees with the exception of the office workers attend these meetings.

Special attention is given to the subject matter and the method of conducting meetings. A poorly conducted or uninteresting meeting makes little impression on the employees. The leaders are chosen from the refinery staff in accordance with their ability. Not everyone is qualified to conduct meetings although he may be entirely sold on safety. Therefore, only those who have the desire and possess the ability are requested to lead meetings.

In all meetings, safety thinking is stressed and, in particular, near accidents are discussed. The interest of employees is easily held on such subjects. Suggestions are requested but not dwelled on

In some departments of the Shell Oil Company's Wood River Refinery the whole department has established records of up to two decades of service without a single disabling injury. This group shows the day shift of seven refinery departments, all of which have a record of better than 15 years without disabling injuries. Included are tool room attendants, 20 years; cooling water systems, 20 years; lube treating heavy oils, 19 years; shop machinists, 18 years; blacksmiths, 18 years; and storehouse, 17 years.

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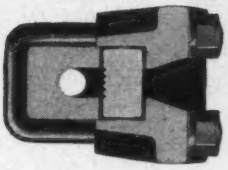

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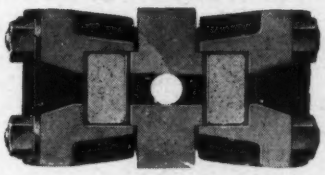

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Directly responsible for putting into practice the precautions which have made possible the outstanding safety record of the Shell Oil Company's Wood River Refinery are the members of the refinery's safety staff. Left to right they are R. A. Randels, B. C. Cole, E. S. Quillen, J. S. Brien, G. L. Moorman, Jr., C. A. Nicolet, J. F. Goldsberry, A. T. Smith and E. B. Wiley, Jr.

for any length of time as in most instances they require investigation and then are handled personally with the suggester. All suggestions are disposed of as quickly as possible by means of a letter advising of their final disposition. Good housekeeping which, no doubt, plays a part in safety work is not allowed to consume too much time in the meetings. Disabling injuries in the plant are thoroughly aired along with action taken to prevent recurrence. The prime purpose of the meeting is to promote the feeling among the employees that they have a duty in safety work and are, in a sense, all safety inspectors.

Active interest of staff members also stimulates the work of the regular inspectors. These inspectors have been trained so that in promoting safety work they are able to obtain the cooperation of the foremen and employees. They have been carefully chosen and possess years of refinery experience. They are men of good personality and by nature are patient and cooperative. They understand that safety cannot be forced but must be obtained through educating the employees to think and want to do a job safely whether an inspector is around or not.

We feel the present record is a result of good leaders, good inspectors, and a live and enthusiastic safety organization which takes pride in the knowledge that through its efforts human suffering and lives have been saved, and that hundreds of hours of time, so precious to petroleum refining on a wartime schedule, have been saved for the manufacture of vital products.

The safety organization at Wood River refinery is a division of the engineering department and consists of James F. Goldsberry, refinery chief engineer, as safety chairman; Ray A. Randels, head safety engineer; A. T. Smith, J. S. Brien, G. L. Moorman, Jr., and C. A. Nicolet, senior inspectors, and E. S. Quillen, E. B. Wiley, Jr., and B. C. Cole, inspectors.

Propose Recommendation For Iron, Steel Relief Valves

A proposed simplified practice recommendation for iron and steel relief valves for petroleum, chemicals, and general industrial services, has been submitted by the Division of Simplified Practice, National Bureau of Standards. These valves are primarily intended for air, gas, vapor and liquid service requirements for oil refineries, gasoline plants, synthetic rubber projects, and chemical plants; also for general industrial service.

The development of this recommendation was undertaken at the request of the Shipbuilding Division of the War Production Board, and is one of several such recommendations proposed for the purpose of insuring adequate production of all types of safety and relief valves for all needs.

The Petroleum Administration for War is the principal claimant agency for the relief valves found in the proposed recommendation and representatives of the construction division of that office collaborated with the segment committee of the Valve Industry Advisory Committee and the National Bureau of Standards in drafting the simplified list of sizes and varieties.

Mimeographed copies of the proposed simplified practice recommendation, upon which comment has been requested, may be obtained upon request to the Division of Simplified Practice, National Bureau of Standards, Washington 25, D. C.

More-Potent Gasoline For Super-Power Planes

A new aviation gasoline, more powerful than any heretofore produced, will be ready for delivery to the B-29 Superfortresses and B-32 bombers now being produced for the attack on Japan, any time military authorities give the word, it was announced August 13 by PIWC Chairman William R. Boyd, Jr.

About 80 percent of the industry's high-octane production capacity is available, with only minor modifications and additions to facilities to produce the new fuel, which Boyd said was perfected primarily to accelerate Allied aerial activities and is of vastly improved octane rating over the gasoline now used, itself the finest the world has ever known.

Boyd explained that the new gasoline cannot be provided on a volume basis until needs in the European theater for 100-octane are lessened. The available refining capacity of the United Nations, he said is now taxed to capacity in supplying the more than 500,000 barrels a day currently required. However, he added, a considerable amount of the new product may begin to flow this fall as the new super-super planes begin their anticipated hammering of the Japanese homeland.

Details of the new gasoline are cloaked in military secrecy, Boyd said, but in essence it is 100-octane gasoline "rebuilt chemically and treated in a manner to squeeze the last drop of potency from the present product." It was developed under the program of the PIWC technical advisory committee for improvement of the quality of aviation gasoline with the use of existing equipment and modifications.

Data Compiled on Fischer-Tropsch Process

The Bureau of Mines has published a survey of scientific material on the preparation and properties of metal carbides and their importance as catalysts in the Fischer-Tropsch process.

The report brings together the more reliable facts on the carbides of iron, cobalt, and nickel in their connection with liquid-fuel production by the synthesis of gases from coal or coke. Its compilation is only one phase in a long series of synthetic liquid-fuel experiments and investigations conducted by the Bureau of Mines in recent years.

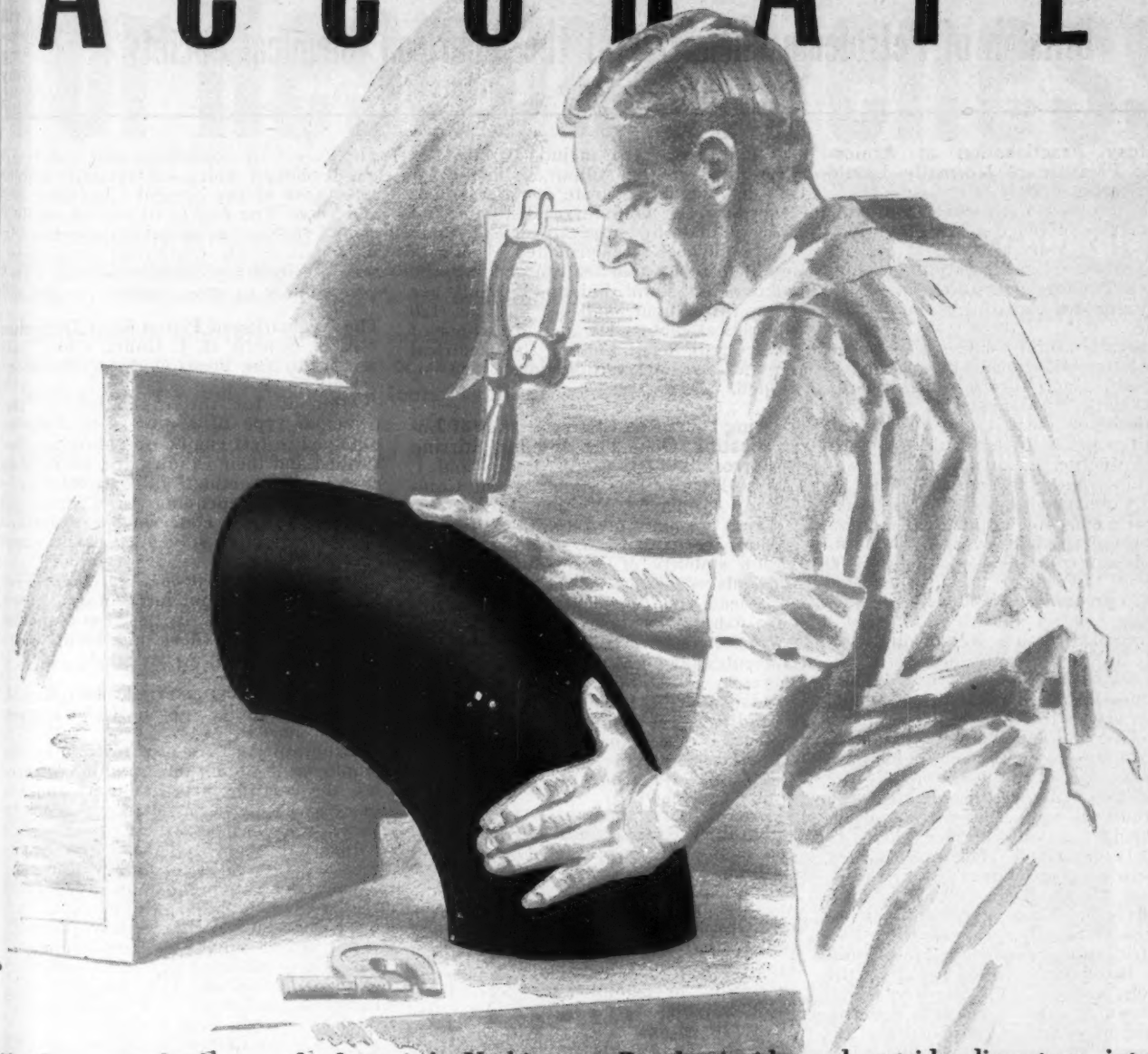
A catalyst, such as the carbides of iron, cobalt and nickel, plays an important part in the Fischer-Tropsch process for converting synthesis gas from coal or coke to oil, since the catalyst determines the speed with which the reaction, or change, takes place, and has a marked influence upon the quality of the fuel produced in the operation.

A copy of the report may be obtained by writing to the Bureau of Mines. Department of the Interior, Washington 25, D. C., for Report of Investigation 3770, "The Preparation and Properties of Metal Carbides with Critical Comment as to Their Significance in the Fischer-Tropsch Synthesis," by L. J. E. Hofer.

Products Line

The Ohio Oil Company has work under way for a 6-inch products pipe line to move 16,000 barrels daily from its refinery at Robinson, Illinois, to Indianapolis, Indiana.

ACCURATE



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ABSTRACTS OF PAPERS

Presented at

Division of Petroleum Chemistry of the American Chemical Society

New York, September 11 to 15, 1944

Laboratory Fractionation at Atmospheric Pressure of Normally Liquid Hydrocarbons. H. J. Hepp and D. E. Smith, Phillips Petroleum Company.

The factors involved in the laboratory distillation of normally liquid hydrocarbons when it is desired to separate near-boiling components are discussed, and suitable fractionating columns are described.

A generally useful column is described wherein the fractionating section is packed with single-turn wire helices, the column being insulated with an especially designed electrical heater which makes it possible to maintain the fractionating section in an adiabatic condition. This column is equipped with an especially designed head provided with electrical means for automatically maintaining the desired reflux ratio. Columns of this design containing up to about 100 equivalent theoretical trays have been found to operate satisfactorily.

A Universal Pressure Rectorying Column. Edgar S. Byron, John R. Bowman, and James Coull, Mellon Institute for Industrial Research and University of Pittsburgh.

Following an introductory review of high vacuum distillation in general, a new type of rectifying column is described. This column, in contrast to all countercurrent contactor types, employs the principle of "multiple redistillation" previously described. [R. M. Schaffner, J. R. Bowman, and James Coull, Trans. Am. Inst. Chem. Engrs. **39** 77 (1943)], but differs in being applicable at all pressures. Basically, it comprises two concentric tubes. Heat is applied uniformly throughout the length of the outer one, and the reflux stream, which flows down its inner surface, is continuously vaporized. Vapor rises in the annular space between the two tubes. The inner tube is uniformly cooled throughout its length, and rotated at such a speed that the condensate formed on it from the vapor is thrown off centrifugally to join the reflux stream. The theory of the performance of such a column is developed in detail, and experimental results are presented showing fair agreement with the ideal predictions. In addition to operation at all pressures, especially high vacuum, these columns have the advantages of very low holdup, being virtually flood-proof, and requiring low reflux ratio.

An Automatic Laboratory Fractionating Column. Victor C. Smith, Arthur L. Glasebrook, Hercules Experiment Station, Hercules Powder Company, Wilmington, Delaware. Charles R. Begeman, and Wheeler G. Lovell, Research Laboratories Division, General Motors Corporation, Detroit.

An automatic laboratory fractionating column, one of a number used for some years for the analytical distillation of close-boiling hydrocarbons, is described in detail. It is made almost entirely of corrosion-resistant metal, including a 10-foot multiwall vacuum jacket. The automatic features include control of heat input to the stillpot, collection of the distillate in separate containers, and recording the volume of distillate and the distillation temperature. Adequate safety devices are provided. Using a modified removable Dufton packing, the column has 50-ml. holdup, 1200 ml. per hour throughout, and as high as 120 theoretical plates. Detailed drawings of the column itself and of the electrical circuits for automatic control are included.

Bearing Corrosion Characteristics of Lubricating Oils. The Indiana Stirring Corrosion Test. C. M. Loane and J. W. Gaynor, The Standard Oil Company (Indiana), Whiting, Indiana.

Data are presented on the effect of various inorganic catalysts upon the corrosion stability of heavy-duty lubricatings oils as measured by the weight loss of a lead strip suspended in a stirring type laboratory test (Indiana stirring corrosion test). An increase of catalyst concentration may increase or decrease the corrosion stability of various oils depending on the type and concentration of additive present in the oil. Lead oxide appears to be a particularly appropriate catalyst for correlation with bearing corrosion data from the standard 36-hour Chevrolet test.

Laboratory Evaluation of Oil Deterioration. R. G. Larsen, Shell Development Company, Emeryville, California.

Detailed consideration is given to the physical-chemical variables involved in the deterioration of engine, turbine, and transformer oils and the factors which are significant in service. It is possible therefrom to establish the conditions most suitable for laboratory tests. Behavior of engine lubricants in the ring-belt area cannot be studied in tests designed for measuring crankcase oil stability but requires specially adapted high-temperature experiments.

Limitations are discussed as well as difficulties in correlating test results with field data. It is concluded that the laboratory methods should be employed not so much to predict the useful life of an oil, but rather to provide a relative rating for a series of oils and information as to their fundamental chemical nature.

Laboratory Evaluation of Some Factors Causing Lubricating Oil Deterioration in Engines. R. E. Burk, E. C. Hughes, W. E. Scovill, and J. D. Bartleson, Standard Oil Company (Ohio).

The deterioration of lubricating oil in internal combustion engines is due largely to oxidation reactions. It is shown that these reactions are primarily catalytic at the engine temperatures in question, being controlled by metal catalysts such as iron, copper, etc. The effects of other possible catalytic materials, such as blow-by gas components, are considered. These observations are applied to a laboratory test procedure for evaluating the service stability of oils. A set of conditions and catalysts are developed which substantially duplicate those of the present Chevrolet engine tests. The degree of reproducibility and of correlation with engine results is shown in detail. Additional procedures are described for determining the tolerance of oils to more severe conditions.

The Evaluation of Piston Skirt Deposits. A. C. Scholp, B. J. Conta, and C. D. Russell, The Texas Company, Beacon, New York.

Methods for the evaluation of the principal type of piston skirt deposits obtained in test engine operation are described and their validity and utility discussed. The methods fall into two general classes, depending on whether or not the deposit concerned can be removed with polar solvents. Certain characteristics of the various type deposits are described and properties given. Test methods most useful for routine deposit determinations are discussed and special methods, useful where additional information is desired, are detailed.

Laboratory Corrosion Tests. R. M. Burns, Bell Telephone Laboratories, New York.

Laboratory corrosion tests may be employed to obtain information concerning the corrodibility of metals and the protective quality of metallic finishes. In these tests it is the practice to simulate natural environmental conditions and to measure rate of corrosion by a variety of methods. Owing to the diversity of the environments in which metals are used, it is not possible to devise a single test which is capable of determining the corrosion resistance of metals under all exposure conditions. The principal features of laboratory immersion, atmospheric, and salt spray tests are described and the usefulness of electrochemical methods in corrosion study is emphasized.

Laboratory Tests to Predict the Performance of Metals Under Service Conditions. D. W. Sawyer and R. B. Mears, Chemical Metallurgy Division, Aluminum Research Laboratories.

If it is desired to predict the performance of metals under service conditions, it is necessary to use a laboratory test which will give results which correlate directly with service results. The most certain method of designing a suitable laboratory test is to simulate the conditions of service as closely as possible. Attempts made to accelerate the laboratory test by intensifying one of the factors encountered in service, often lead to the obtaining of misleading results.

Several examples of laboratory tests illustrating these points are described in the paper.

The Application of the Carbonium-ion Theory to the Alkylation of Isoparaffins. F. G. Ciapetta, The Atlantic Refining Company, Philadelphia.

The reactions of paraffin and olefin hydrocarbons in concentrated sulfuric acid indicate that the molecular hydro-

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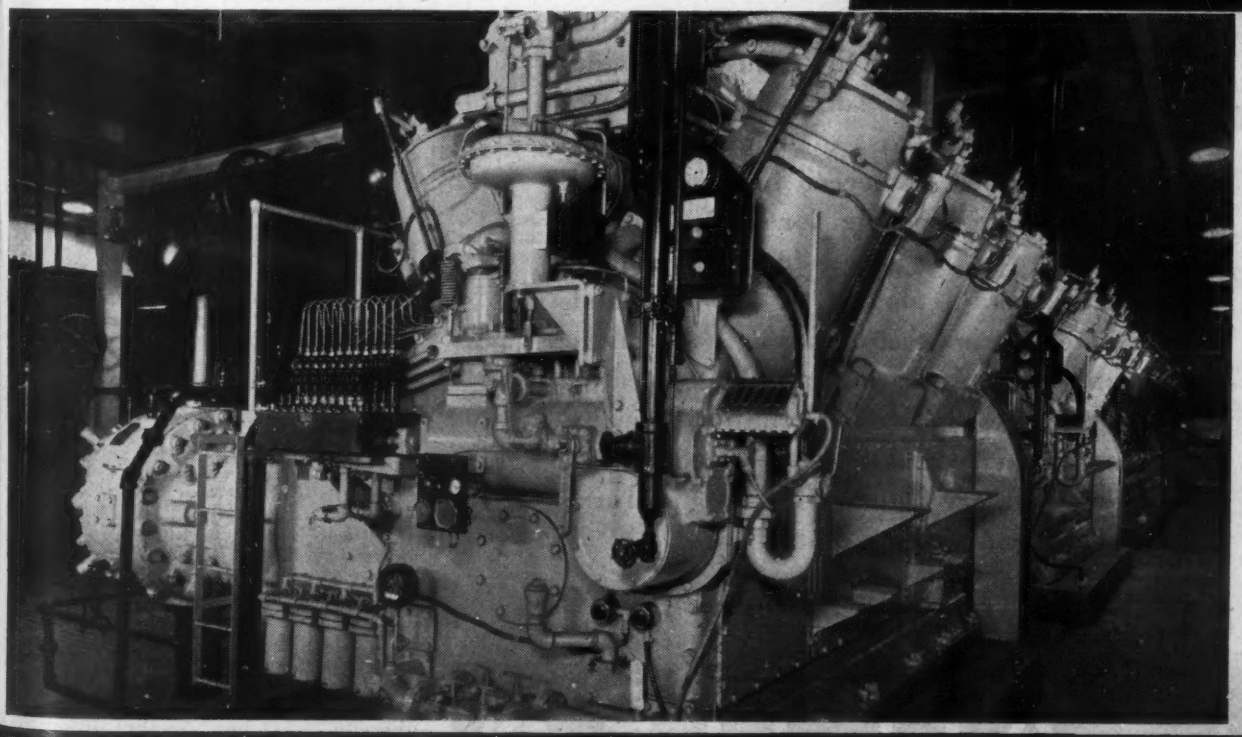

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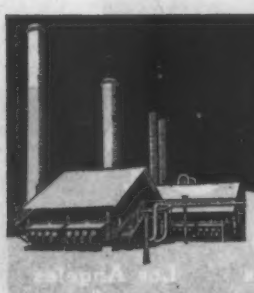

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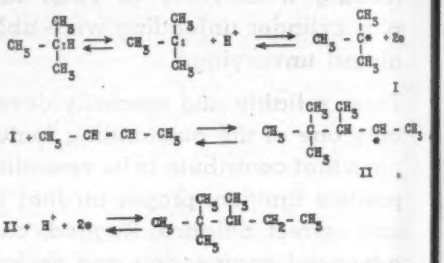
genation-dehydrogenation properties of this catalyst play an important role in the alkylation of isoparaffins with olefins. The marked similarity of the carbon skeletons of the hydrocarbons produced in the alkylation of isobutane with butenes, and the copolymerization of isobutenes with normal butenes in less concentrated acid, suggests the formation of a carbonium-ion intermediate during the alkylation reaction similar to that postulated by Whitmore for the polymerization reaction.

The proposed mechanism suggests the initial activation of the isoparaffin through ionization and partial dehydrogenation to form a carbonium-ion. This ion then reacts with the olefin to form a higher-molecular weight carbonium-ion, which on hydrogenation forms the saturated product. The mechanism is illustrated by the alkylation of isobutane with butene-2. (The carbon atom deficient in electrons is indicated by an asterisk.)



Rearrangement of the carbonium-ion (II) which may involve a shift of either a methyl group or a methyl group and a hydrogen atom, together with their bonding pairs of electrons, explains many of the primary products observed experimentally. Depolymerization of (II) offers a logical basis for the presence of many of the secondary products found. This mechanism also explains the necessity for employing certain reaction conditions to obtain satisfactory alkylation of isoparaffins with olefins.

Investigation of the Mechanism of Butane Isomerization Using Radioactive Hydrogen as a Tracer. T. M. Powell and E. B. Reid, California Research Corporation.

In reviewing the type of catalysts that effect isomerization at low temperatures, it is noted that they include substances that have large central groups from which a hydrogen atom protrudes. Examples are aluminum chloride, phosphoric acid, perchloric acid, and benzene sulfonic acid.

The results of tritium exchange between hydrogen, hydrogen chloride, and butanes during isomerization are presented. These show that exchange of tritium in hydrogen chloride to butane is large compared to exchange of tritium in hydrogen to butane.

It is believed that catalysis of butane isomerization with aluminum chloride involves the process of providing a hydrogen atom, by means of a complex such as $HAlCl_4$, for entering the bonding sphere of a carbon atom thereby displacing a methyl group from its normal position.

Specific Surface and Particle Size Distribution of Various Silica-Alumina Gels. P. B. Elkin, C. G. Shull, and L. C. Roess, The Texas Company.

Three series of silica-alumina gels of various concentrations made by (A) precipitation in sequence, (B) mixing wet gels, and (C) impregnation of par-

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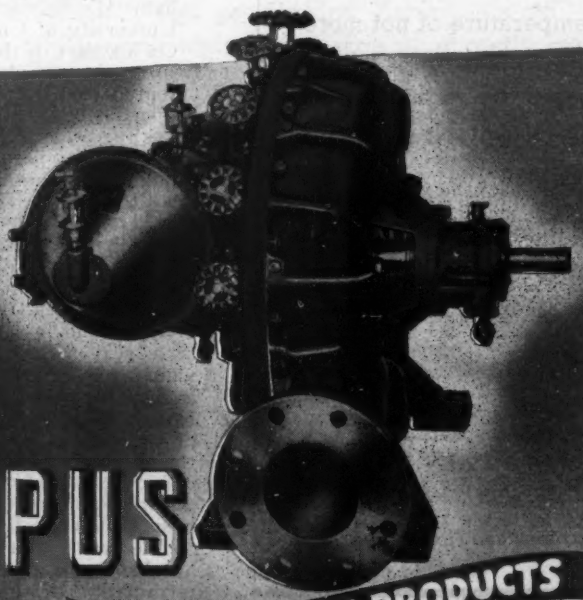

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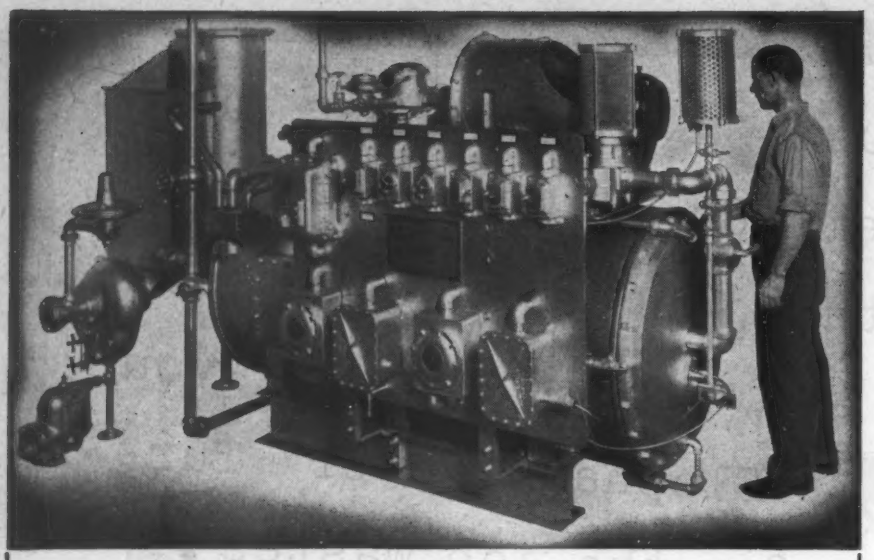

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tially dried silica gel were examined by nitrogen adsorption, small angle x-ray scattering, and x-ray diffraction. Specific surfaces were smaller for (A) and larger for (B) than those expected for mixtures of the dried silica and alumina gels. Maxima in curves for specific surfaces versus alumina content for (B) and (C) at about 5 wt percent correlated with minima in average particle size. No alumina was detected by x-ray diffraction for gels containing as much as 26 wt. percent alumina.

Nitrogen Adsorption Isotherm Studies of a Supported Catalyst and its support. The Effect of Sintering on Surface Area and Structure. Herman E. Ries, Jr., Robert A. VanNordstrand, and John W. Teter, Research and Development Department, Sinclair Refining Company, East Chicago, Indiana.

Low-temperature nitrogen adsorption isotherms have been determined for the following materials after heat treatments at the indicated temperatures: a supported catalyst, 340°, 400°, 500°, 600°, and 650°; the diatomaceous support, 340° and 650°; and the unsupported catalyst, 340°. Area values (340°) are respectively 119.8, 20.7, and 53.5 sq. m. per gram. The supported catalyst loses 5% of its area at 500°, 26% at 600°, and 75% at 650°.

The area of this support is in fair agreement with that of a model based on electron microscope pictures.

An adsorption-desorption isotherm determination (four days) on the supported catalyst demonstrates hysteresis. The possible importance of pore orifice dimensions calculated from the desorption curve is indicated.

Va/Vm isotherms are discussed in relation to specificity of adsorption and pore size.

The Surface of Solids. I. An Absolute Method for the Determination of the Area of a Finely Divided Crystalline Solid. II. A Vapor-Absorption Method for the Determination of the Area of a Solid Without the Assumption of a Molecular Area, and the Areas Occupied by Nitrogen and Other Molecules on the Surface of a Solid. William D. Harkins and George Jura, University of Chicago.

On account of the importance of catalysts in the petroleum industry it seems essential to determine their physical properties. Of the strictly physical properties the area of the surface of a porous solid catalyst seems to be of the most fundamental significance, not only from the standpoint of the importance of the area itself, but in addition a knowledge of the area is necessary for the calculation of other important physical properties. The question arises as to what extent the area determined for a finely divided solid is a true or real area. If it is a real area, then the accuracy to which it is determined should be put to a rigorous test. The best method previously used for obtaining a knowledge of the area is based upon the value of the area occupied by the adsorbed molecules, and unfortunately this is not known, but must be estimated on the basis of certain hypotheses.

The writers have now developed (1) an absolute, accurate method for the determination of the area of a crystalline powder, and on the basis of this (2) an adsorption method for the determination of the area of a porous or a non-porous solid. If log (p/p_o) is plotted against

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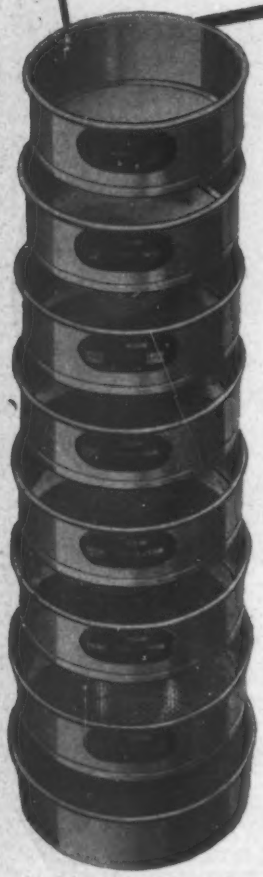

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$1/v^2$; where v is the volume (STP) of vapor adsorbed per gram, then from the slope (s) of the linear portion of the plot obtained with nitrogen, the area Σ in sq. meters per gram is given by

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if the vapor is that of nitrogen. With other vapors, the value of the constant is different.

Carbon Formation in Catalytic Cracking. Alexis Voorhies, Jr., Esso Laboratories, Standard Oil Company of Louisiana, Baton Rouge.

In catalytic cracking, both fixed-bed and fluid, it has been found that there is an intrinsic uniformity in the way that the carbon deposit on the catalyst increases with the length of time since the catalyst was last regenerated. For all the data examined, the amount of carbon deposited on the catalyst at given conditions is, within limits, independent of the hydrocarbon feed rate. From this study, correlations have been derived that define mathematically the interdependence between feed stock conversion, feed rate, and length of period between catalyst regenerations.

A speculative hypothesis is advanced as a possible explanation of the mechanism of carbon formation.

The Fluidized Fixed Bed. A Method for Contacting Solids with Gases and Vapors. Charles L. Thomas and James Hoekstra, Universal Oil Products Company.

The passage of gases or vapors upward (counter to gravity) at controlled rates through a mass of powdered solid produces the "fluidized fixed bed." The passage of the gas or vapor causes the powdered solid to become mobile so that it moves about, resembling an agitated liquid. The particle size of the powder is regulated so that little of it is carried out of the reaction zone with the gas or vapor.

The fluidized fixed bed is particularly adapted to catalytic reactions in which a reaction occurs that is accompanied by large heats of reaction. The movement of the powdered solid tends to prevent the formation of localized high temperature zones "hot spots."

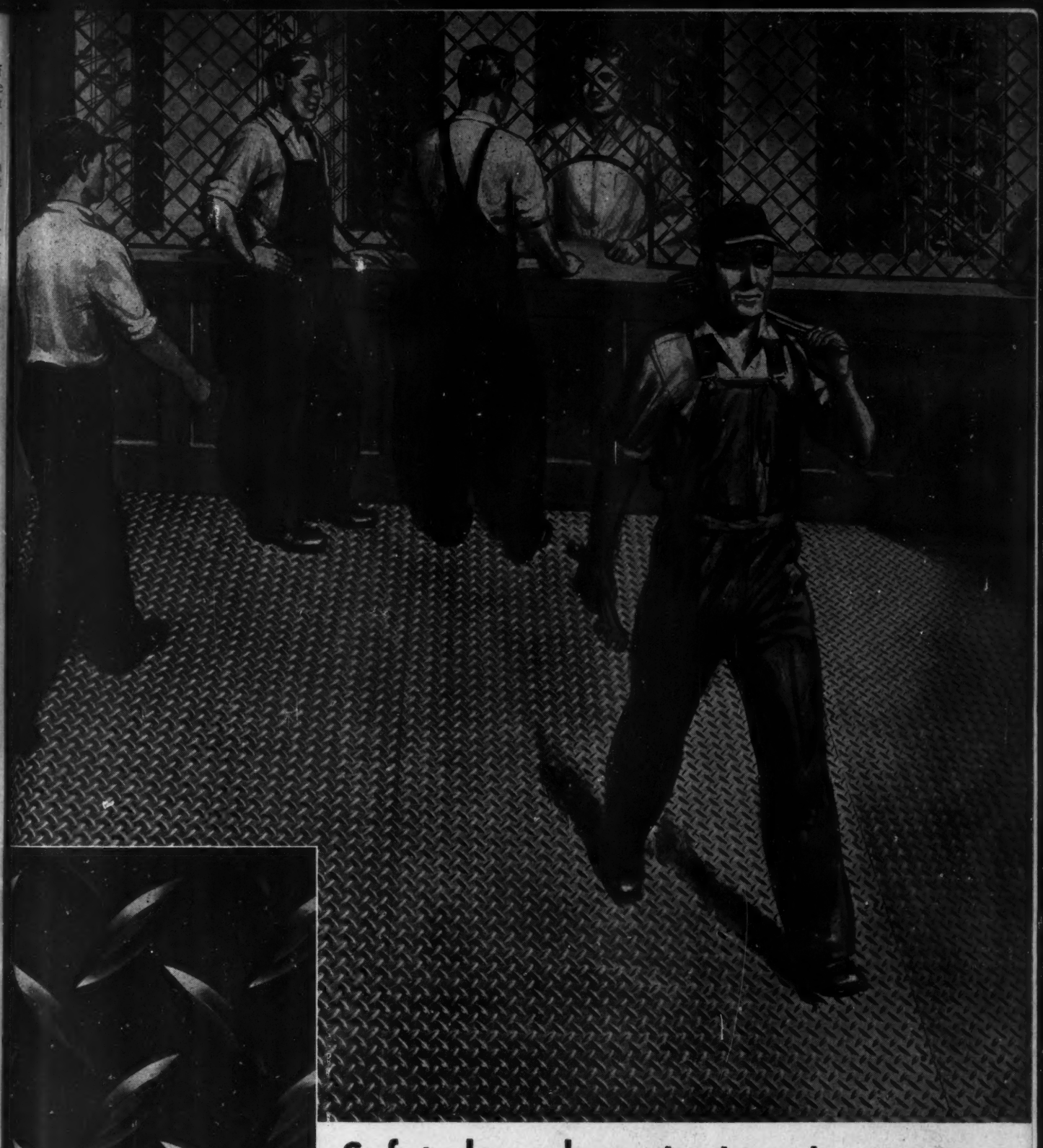
Examples are given showing the application of the fluidized fixed bed to the catalytic cracking of gas oil and a hydrogen transfer treatment of an unsaturated gasoline.

Polymerization of Ethylene. V. N. Ipatieff and V. Haensel, Universal Oil Products Company.

The polymerization of ethylene at elevated temperatures and pressures has been investigated using a flow method. The ensuing reactions were dependent upon the contacting material, pressure, and temperature. An empty chromium-molybdenum steel tube produces considerable carbon formation and promotes the production of paraffin hydrocarbons in the lower boiling fractions of the liquid product. The presence of metal chips having the same composition as the reaction tube enhances the carbon formation still further.

When porcelain or quartz chips were used as fillers, the reaction of true polymerization and depolymerization predominated. This was especially evident at lower pressures, that is, 30 to 50 atmospheres. The liquid product showed the same olefinic character as the C_5—C_6 fraction.

In the presence of an active silica-



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1/4"	3,366,990	370.37	304,820	198.13	381,020	60.96
1/8"	824,570	90.70	74,650	48.52	93,310	14.93
1/16"	213,000	23.43	19,280	12.53	24,110	3.86
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alumina-zirconia catalyst, the reactions of hydrogen transfer became more pronounced. This led to a more saturated liquid product and a higher yield of high boiling residue. The hydrogen transfer reaction was the predominant reaction at higher temperatures (530° C.) and only a small part of the product retains an olefinic character.

Reactions of Hydrocarbons in the Presence of Cracking Catalysts. V. The Polymerization of Gaseous Olefins. Charles L. Thomas, Universal Oil Products Company.

Synthetic cracking catalysts polymerize propylene and the butylenes. The butylenes polymerize at 165° C. and 45 kg./sq. cm. pressure. Propylene polymerizes at 250° to 300° C. and 50 kg./sq. cm. Under the conditions studied.

1. Silica xerogel, alumina, or zirconia are not polymerization catalysts.
2. Silica-alumina, silica-zirconia, silica-alumina-zirconia, and silica-alumina-thoria composites are catalysts.

During use the catalysts become coated with a carbonaceous deposit that lowers the catalyst activity. Removal of this deposit by combustion with air regenerates the catalyst.

The polymers are liquids, most of which boil within the gasoline range. The hydrogenated butylene polymer has an octane number of 95.

Catalytic Isomerization of 1-Hexene. Russell G. Hay and C. W. Montgomery, Gulf Research & Development Company, and James Coull, Chemical Engineering Department, University of Pittsburgh.

The skeletal isomerization of 1-hexene was investigated in the temperature range 285° to 500° C. and the effects of various catalysts and changing space velocity at comparable temperatures were studied. The products were chiefly methylpentenes with lesser amounts of dimethylbutenes. Lower boiling and higher boiling olefins were also formed in minor proportions.

The evidence obtained indicated that the 2-methylpentenes were primary isomerization products while the dimethylbutenes were secondary products. At 0.6 $hr.^{-1}$ space velocity the greatest amount of isomerization occurred at 300° to 350° C. Below this temperature, the reaction rate decreased with decreasing temperature, and at higher temperatures the equilibria apparently became less favorable for the branched hexenes.

The Commercial Isomerization of Light Paraffins. B. L. Evering, N. Fragen, and G. S. Weems, Standard Oil Company (Indiana), Whiting, Indiana.

Five commercial plants are described in which normal butane, normal pentane, and normal and less highly branched hexanes are converted to iso-compounds for aviation gasoline manufacture. Feed stock mixed with anhydrous HCl is passed upward in small liquid drops through a liquid aluminum chloride-hydrocarbon complex catalyst. Fairly pure neohexane can be made by fractionation and recycling the remaining hexanes. Hexanes and pentanes may be isomerized together. Very high liquid yields are obtained.

Catalysis in Synthetic Liquid Fuel Processes. H. H. Storch, U. S. Bureau of Mines, Pittsburgh.

A review is presented of the development of catalysts for the hydrogenation

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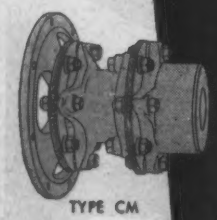
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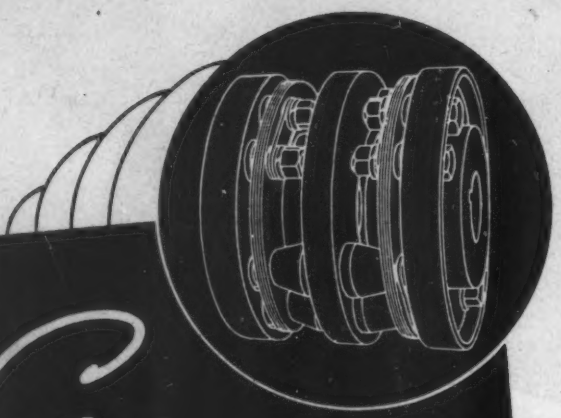

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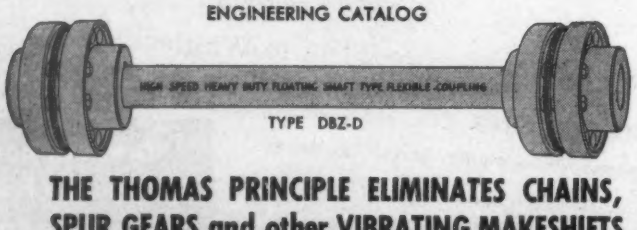

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of carbon monoxide to yield alcohols and hydrocarbons. The development of the Fischer-Tropsch process for the synthesis of hydrocarbons from hydrogen and carbon monoxide has yielded sufficient data so that the essential outlines of the reaction mechanism can be distinguished. This reaction is apparently of first order with respect to $2H_2 + 1CO$ but is greatly complicated by at least two types of retardation by the reaction products. Data are reviewed on effect of partial pressure of the reactants and the products, of temperature, of pretreatment or conditioning of the catalyst surfaces, and of the poisoning action of sulfur and resin-forming compounds.

The development of high-pressure processes for the hydrogenolysis of coal and oil has involved an intensive search for suitable catalysts. In the primary or liquid-phase stage of coal hydrogenation the maintenance by catalytic hydrogenation of a high concentration of hydrogen carriers is important. These carriers are hydroaromatic compounds such as tetrahydronaphthalene and dihydroanthracene that readily yield their hydrogen to the unsaturated compounds resulting from the normal decomposition of the coal. Disproportionation reactions that yield aromatics and more saturated naphthenic compounds also occur. The best catalysts for liquid-phase coal hydrogenation are reactive compounds of tin, molybdenum, or tungsten. About 0.1 to 0.5 percent of such a catalyst is added in finely divided form to the coal-oil slurry pumped into the high-pressure converters. It is also desirable to add 0.5 to 0.8 percent of a volatile chlorine compound which acts as a "splitting" catalyst, accelerating the reduction in molecular weight of the primary products. The rates of primary coal liquefaction and of oxygen elimination are influenced only to a minor extent by the presence of catalysts. Hydrogen at high pressures and catalysts are essential for the maintenance of a high concentration of hydrogen carriers. The desirability of high-pressure hydrogen is of kinetic and not of thermodynamic nature.

The art of hydrogenolysis of "gas oil" from coal hydrogenation middle oils or from petroleum is in a highly developed state. Catalysts have been found that convert gas oil to a high octane, high rich mixture performance gasoline. These catalysts are used as a body of pellets through which are passed the oil vapors plus a large excess of hydrogen at 200 to 300 atmospheres pressure plus hydrogen sulfide at about 0.5 atmosphere pressure. The desirability of high-pressure hydrogen is largely of kinetic nature. Very little, if any, of the hydrogen used appears in the liquid product; most of it is consumed in the production of normally gaseous hydrocarbons. The function of the hydrogen sulfide appears to be to prevent reduction of the tungsten or molybdenum disulfides used as catalysts. It is probable, however, that this explanation is incomplete. Little is known about the kinetics of oil hydrogenolysis. The reactions are essentially oriented dealkylations and splitting reactions, cyclizations, and isomerizations. A possible function of the large excess of hydrogen used is to prevent polymerization reactions whose products would foul the catalyst surfaces. The high iso- to normal butane ratio in the gaseous products of catalytic cracking and of hydrogenolysis of gas oils must

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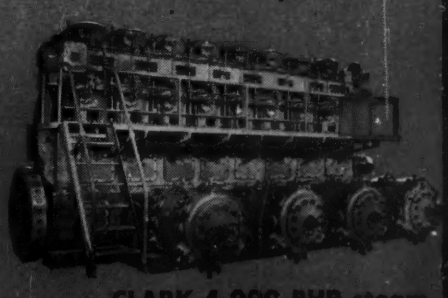

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be explained by any proposed mechanism of the splitting reaction.

Production of Isoparaffin Hydrocarbons by Cracking of Petroleum Fractions in the Presence of Aluminum Chloride. V. I. Komarewsky and Lee Warson, Department of Chemical Engineering, Illinois Institute of Technology.

The cracking of gas oils, naphthas, and selected fractions of straight-run products was studied under various conditions of temperature, pressure, and reaction time in the presence of aluminum chloride and hydrogen chloride. The main results obtained in the course of this work were: A. The gasoline obtained as the result of aluminum chloride cracking of straight-run distillates yields an 80-octane product with good tetraethyl lead susceptibility. B. The products were composed mainly of isoparaffin hydrocarbons. C. Similar products were obtained from charging stocks of various origin. D. The cracking reaction could be directed, so that a product with desired end point would result. E. Isobutane (34% by volume) and isopentane (29% by volume) was obtained based upon the charges. F. The mechanism of the reactions was discussed

Pilot-Plant Development of the Fluid Catalytic Cracking Process. L. E. Carlsmith and F. B. Johnson, Esso Laboratories, Standard Oil Company of Louisiana, Baton Rouge.

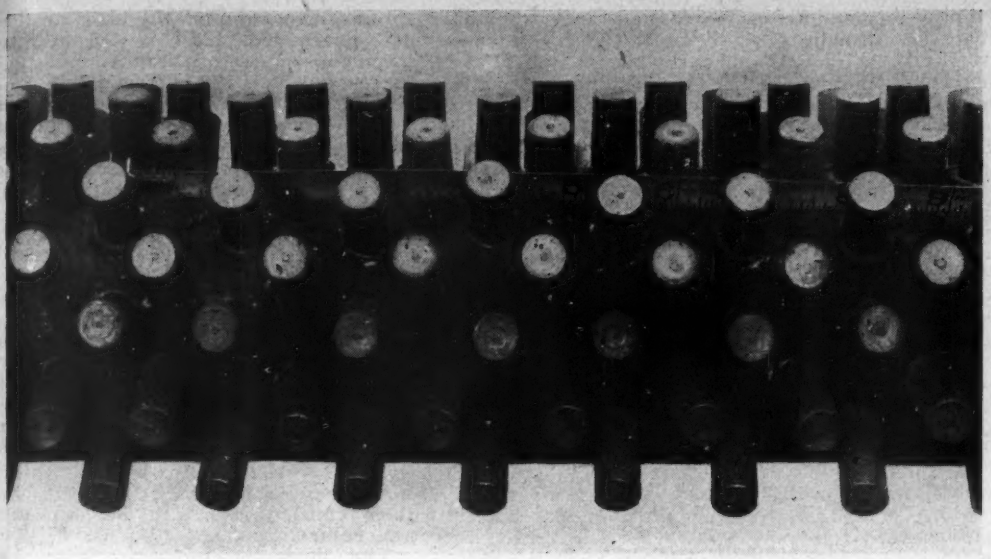
The fluid catalyst cracking process, now extensively used nationwide, was developed by intensive pilot-plant work to signally successful commercial usage. The pilot-plant equipment used in this development comprised a variety of sizes from small laboratory units to a semiplant-scale unit of nominal 100 B/D feed capacity. The 100 B/D plant located at Baton Rouge was relied on for the major part of the process data and engineering and equipment studies required for the commercial designs. A description of this unit and of a smaller unit of 2 B/D capacity also located at Baton Rouge is given. The various engineering studies made are discussed and type of results obtained indicated.

The original 100 B/D plant, which was used to pilot the first model of the commercial units, was later modified to a simpler design which has been incorporated in the later model full-scale plants. The results obtained on both designs have been translated to the commercial scale with singular accuracy.

Catalytic Cracking of Cuts from Coastal Crude Oil. D. B. Ardern, R. H. Newton, and G. L. Barcus, Catalytic Development Corporation.

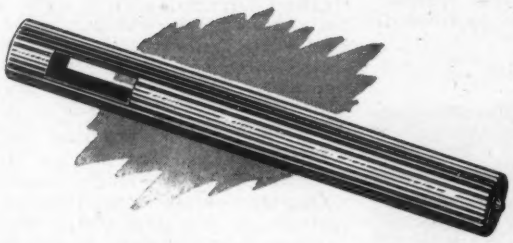
To obtain basic data on the chemistry of catalytic cracking, four narrow boiling cuts of Coastal crude oil having A.S.T.M. mid boiling points of 307°, 406°, 543°, and 687° F. were cracked over Houdry synthetic silica-alumina catalyst at conditions of temperature (650-900° F.) and space velocity (0-2-2.0) chosen to obtain variation in the severity of cracking. Dependent variables, pressure and catalyst activity, were controlled to give catalyst deposits equivalent to those obtained in plant operation.

The composition of the cracked products was found to vary regularly with the severity of cracking. The greater the severity the greater was the concen-



Close-up view shows alignment of the studs on the tubes. The uniformity of the weld gives satisfactory results and a strong, easily accomplished job.

LAGGING MAGNESIA BLOCKS



The Nelson Lagging Stud has been especially developed for securing magnesia blocks to heat exchangers, storage bins, tanks, etc. Rapidly welded into position they hold the blocks securely to the metal. Plastered over, the heads act as reinforcing. To save both time and material in this important operation use the Nelson Lagging Stud. *Write today for complete information to:*

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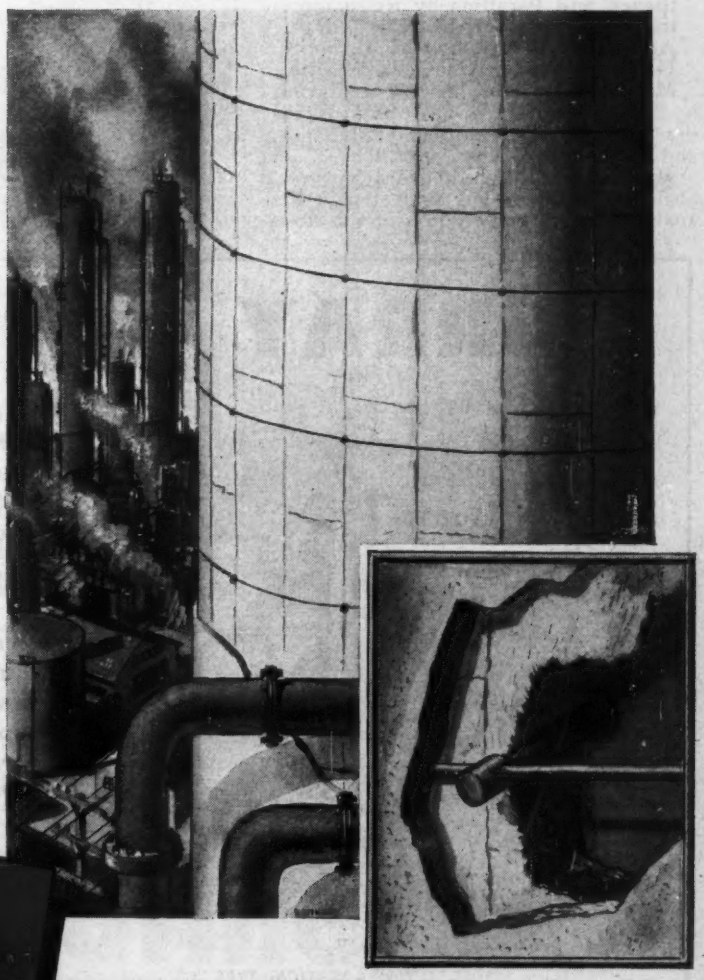


NELSON STUD WELDERS

The studs are welded in rows to the tower. Wire is run through the slots and left slack. The magnesia blocks are slipped under into position and the wire tightened down to secure them. The entire unit is then covered with plaster to complete the work.

tration of aromatics in the cracked product. Indication was obtained that the maximum concentration of cracked naphthenes will occur at moderate cracking severity. The summation of moles of ring compounds decreased as severity increased, indicating a destruction of ring compounds and no net increase in ring compounds formed from chain material. The increase in aromatics was always less than the decrease in naphthenes. Only about 40% of the naphthenes destroyed appeared as aromatics. However, the production of hydrogen was much less than would correspond to simple dehydrogenation of naphthenes to aromatics.

At conditions of reasonably constant severity, the total production of olefins increased with increasing boiling range, while total isoparaffin production decreased. Both trends were most evident in the lighter boiling compounds. The ratio of iso to normal saturated hydrocarbons did not appear to vary appreciably with charging stock or cracking conditions. In the lower boiling aromatics produced, the weight ratio of benzene : toluene : xylene averaged 1:6:16 although varying somewhat with conditions.

Determination of Aromatics, Naphthenes, and Paraffins by Refractometric Methods. R. M. Gooding, N. G. Adams, H. T. Rall, and H. M. Smith, U. S. Bureau of Mines, Bartlesville.

Methods are described for analyzing hydrocarbon mixtures up to 320° F. for their content of paraffins, naphthenes, and aromatics. In the range to 243° F. most of the individual hydrocarbons can also be estimated. The first step in the analysis is the fractionation of the samples into narrow-boiling-range fractions usually of 1° C. or less. Densities and refractive indices for the sodium D and mercury g lines are determined at 20° C. for each fraction. Using modified Kurtz and Headington refractivity intercept-density charts for boiling intervals of about 10° C. the naphthenes and paraffins can be determined. The aromatics at present are preferably determined by specific dispersion methods, but with some loss in accuracy the same refractivity intercept-density charts may be used. The development of these charts from both experimental and literature data is discussed and illustrated.

Determination of Aromatics in Light Petroleum Distillates by the Use of Specific Dispersions Between the Sodium D Line and the Mercury g Line. H. M. Thorne, Walter Murphy, and John S. Ball, U. S. Bureau of Mines, Petroleum Experiment Station, Laramie.

The aromatic content of a hydrocarbon mixture in the gasoline boiling range containing no olefins or diolefins may be determined from the refractive indexes for the mercury g and the sodium D lines, and from the density, all determined at 20° C. The specific dispersion of the mixture is calculated by the equation:

$$S_s = \frac{n_g^{20} - n_D^{20}}{d_4^{20}} \times 10^4$$

The percent aromatics in the mixture may then be obtained from the equation:

$$W = \frac{S_s - 122.4}{S_a - 122.4} \times 100 + C$$

Where W is the weight percent of aromatics in the sample, S_s is the specific dispersion of the sample, S_s is the specific dispersion of the aromatic being determined, 122.4 is the average specific dispersion of paraffins and naphthenes, and C is the correction to compensate for the deviation of the percent aromatics-specific dispersion from a straight-line relationship. The values of specific dispersion for the several aromatics are: benzene, 248.4; toluene, 241.4; ethylbenzene, 228.1; *o*-xylene, 234.8; *m*-xylene, 237.1; *p*-xylene, 238.2; and isopropylbenzene, 215.8.

Determination of Basic Nitrogen in Hydrocarbon Feed Stocks. Leon Donn and Harry Levin, The Texas Company, Beacon, New York.

Because basic nitrogen compounds in hydrocarbon feed stocks, though present in extremely low concentrations, are of great importance in refinery operations, it is necessary to have a method for determining these compounds so their concentration can be measured and controlled.

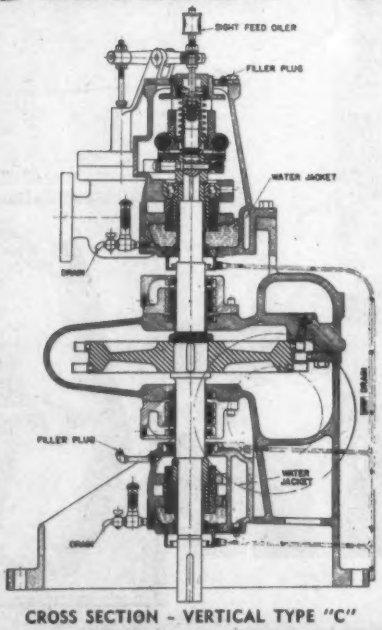
The obvious methods are unsuitable because of the peculiar problems presented by the nature of the sample, principally that of collecting the base in aqueous media.

The proposed method consists of treating liquefied sample with substantially nonaqueous standard acid, which neutralizes and fixes the basic nitrogen compounds, evaporating the hydrocarbon gases and titrating the excess acid.

A Method of Determining Carbon in Catalyst Deposits. James Hoekstra, Universal Oil Products Company.

In many catalytic reactions of hydrocarbons at elevated temperatures, the catalyst accumulates a carbonaceous deposit which is removed by oxidation

MURRAY VERTICAL TURBINES



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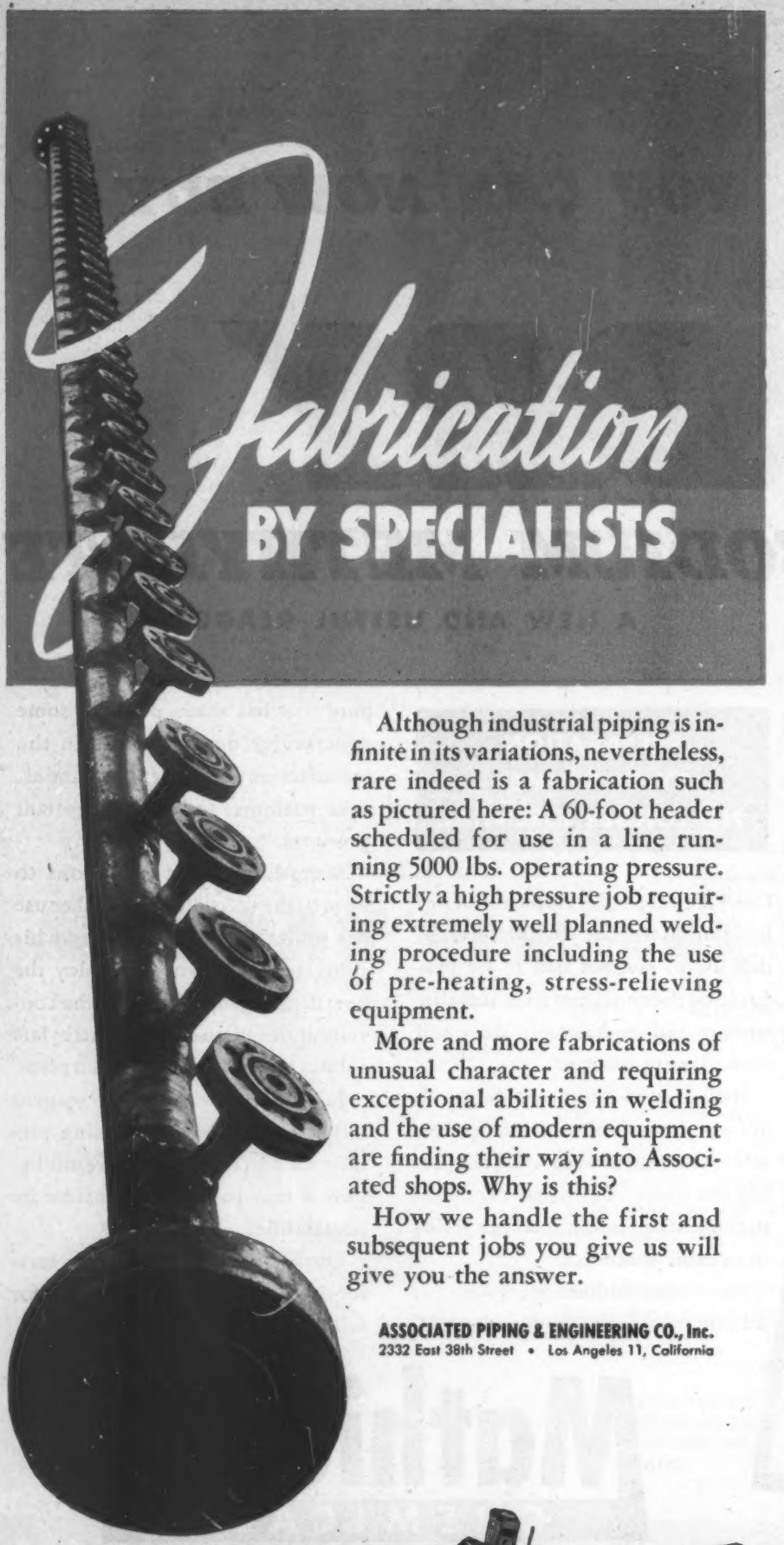

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in a stream of air. Determining carbon in the deposit on a catalyst which is to be regenerated *in situ* involves sampling a gas stream of varying rate and composition. In the method described the sampling is accomplished automatically by means of a series of capillary tubes, and carbon in the sample is determined by oxidation of carbon monoxide to carbon dioxide which is absorbed in Ascarite. The accuracy of the method is shown by a comparison of the results with those obtained by Orsat analysis of samples collected manually.

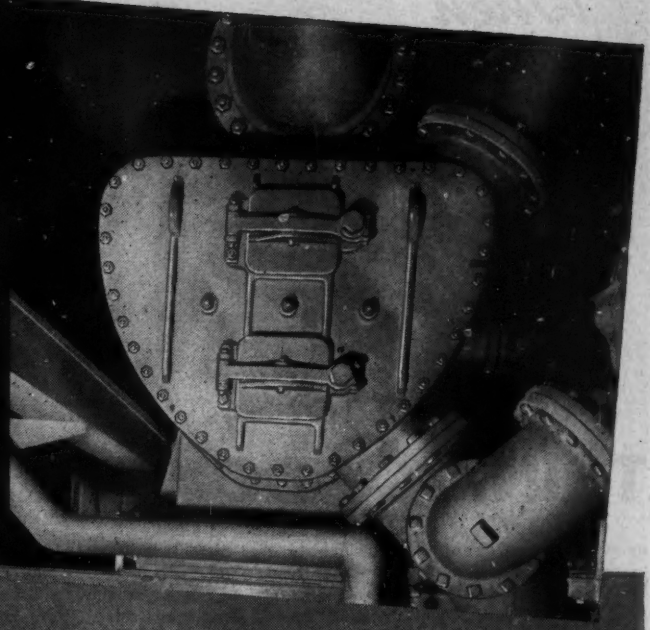
Determination of Tetraethyllead in Gasoline. Versatile Direct Evaporation Methods. Louis Lykken, R. S. Treseder, F. D. Tuemmler, and Victor Zahn, Shell Development Company, Emeryville, California.

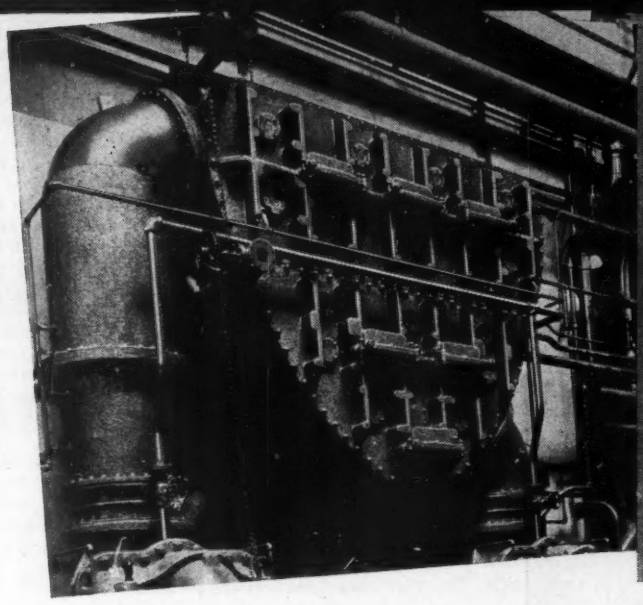
Two methods of analysis involving direct evaporation of sample with decomposition agent are described that allow accurate quantitative analysis of lead in all types of gasoline, special motor fuel blends, and tetraethyllead fluid, regardless of the chemical constituents present. These methods, which require no elaborate apparatus, are the result of a systematic review and investigation of existing methods for the decomposition of tetraethyllead in gasoline and for the determination of lead in soluble inorganic residues. The proposed methods convert the tetraethyllead to inorganic lead by mixing with cold hydrochloric acid or iodine, evaporating the resulting mixture to dryness, and removing the organic matter by oxidation with nitric, perchloric, or sulfuric acids, depending on the nature of the decomposition used. The lead in the inorganic residue is determined by precipitating with a measured amount of dichromate solution and determining the excess dichromate by iodometric titration. For commercial gasolines, the reproducibility (different operators) of the methods is within 0.02 ml. of tetraethyllead per gallon; for commercial tetraethyllead fluids, it is 0.4 percent lead or better.

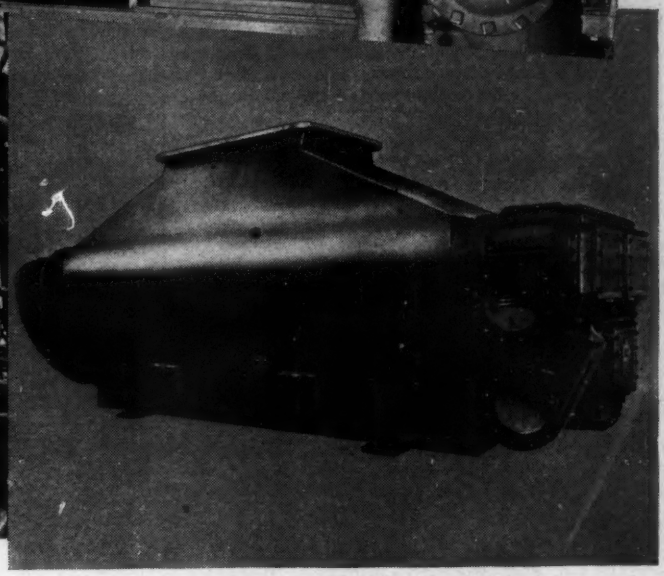
The Determination of Metals in Lubricating Oils. K. R. Fitzsimmons, Louis Lykken, and Garrard Wyld, Shell Development Company, Emeryville, California.

Detailed procedures are given for the determination of lead, copper, cadmium, barium, tin, silica, zinc, iron, aluminum, calcium, magnesium, and alkali metals in new or used lubricating oils without interference from other elements such as sulfur, phosphorus, and chlorine. In the general procedure for all elements except lead, the oil is ashed by ignition in air, the ash is treated with acid, and copper, cadmium, tin, silica, and barium are obtained in the residue after adding hydrogen sulfide and sulfate ion. Iron, aluminum, and zinc are separated from the remaining ions as hydroxyquinolates. For the principal metals, the general method is accurate to ±5 percent of the amount present. In the simplified, direct method, the oil is oxidized with nitric and sulfuric acids, and the lead is determined as lead sulfate after removing interfering elements; iron and copper are determined colorimetrically either on the ash or on the residue obtained after oxidation with nitric and sulfuric acids. The direct method is accurate to ±0.01 percent lead and ±0.001 percent iron and copper, regardless of the other elements present. Data are given on the application of the

Marine? Industrial? ...or Utility?







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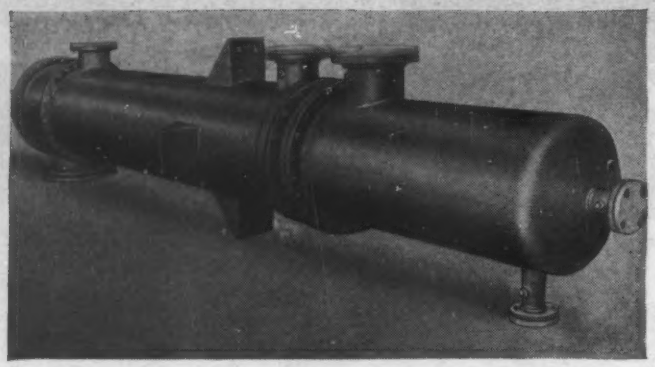

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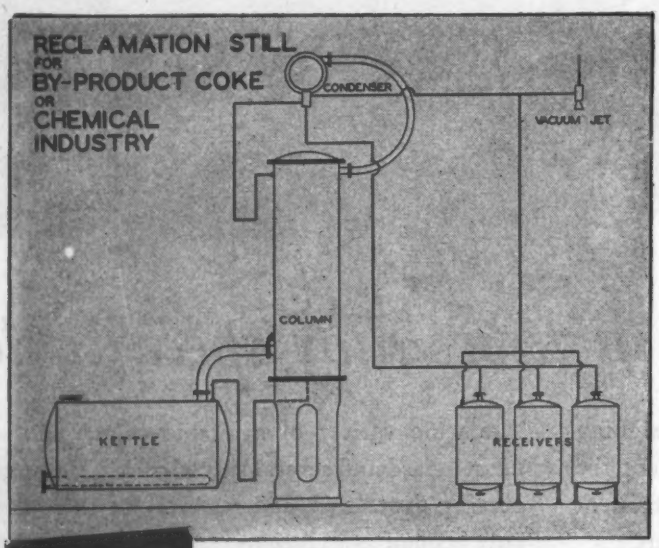

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method to synthetic oil samples and inorganic solutions.

Method for Determining the Viscosity Gravity Constant of Petroleum Oils From Their Viscosities at 130° F. T. A. Petry, Socony-Vacuum Oil Company.

The viscosity gravity constant is an arbitrary index developed by Hill and Coats [J. B. Hill and H. B. Coats, Ind. Eng. Chem., **20** 641-4 (1928)] for differentiating between petroleum lubricating oil fractions of various degrees of paraffinicity. The constant is calculated from the API or specific gravity of the oil at 60° F. and its Saybolt Universal viscosity at 100° or 210° F. The present study has been made in order to extend the usefulness of the V.G.C. by permitting calculations of the constant from Saybolt Universal viscosities measured at 130° F.

The method employed for deriving the V.G.C. for 130° F. viscosity measurements was similar to that employed by the original inventors. The resulting relationship is presented in nomograph form.

Critical Solution Temperatures of Solvents with Cyclic Hydrocarbons. Alfred W. Francis, Socony-Vacuum Oil Company, Paulsboro, New Jersey.

Critical solution temperatures are reported for sixty organic solvents each with one or several of thirty-five aromatic hydrocarbons and three naphthenes. For each solvent the points agree approximately with a smooth function of the total number of paraffinic carbon atoms in the side chains of the hydrocarbons. The temperatures are nearly the same for corresponding derivatives of benzene and naphthalene, so that they may be used to estimate the paraffinicity. Moreover, in the case of alkylbenzenes the temperatures are nearly parallel with the boiling points of the hydrocarbons.

The effects of substituent groups in the solvents upon miscibility are estimated. The hydroxyl, amino, and carboxyl radicals raise the temperatures roughly 200° C. or more, and the nitro group about 150° C. Other radicals have much less effect.

Selectivities of solvents for aromatic hydrocarbons with respect to paraffins are about six times as great as those for naphthenes.

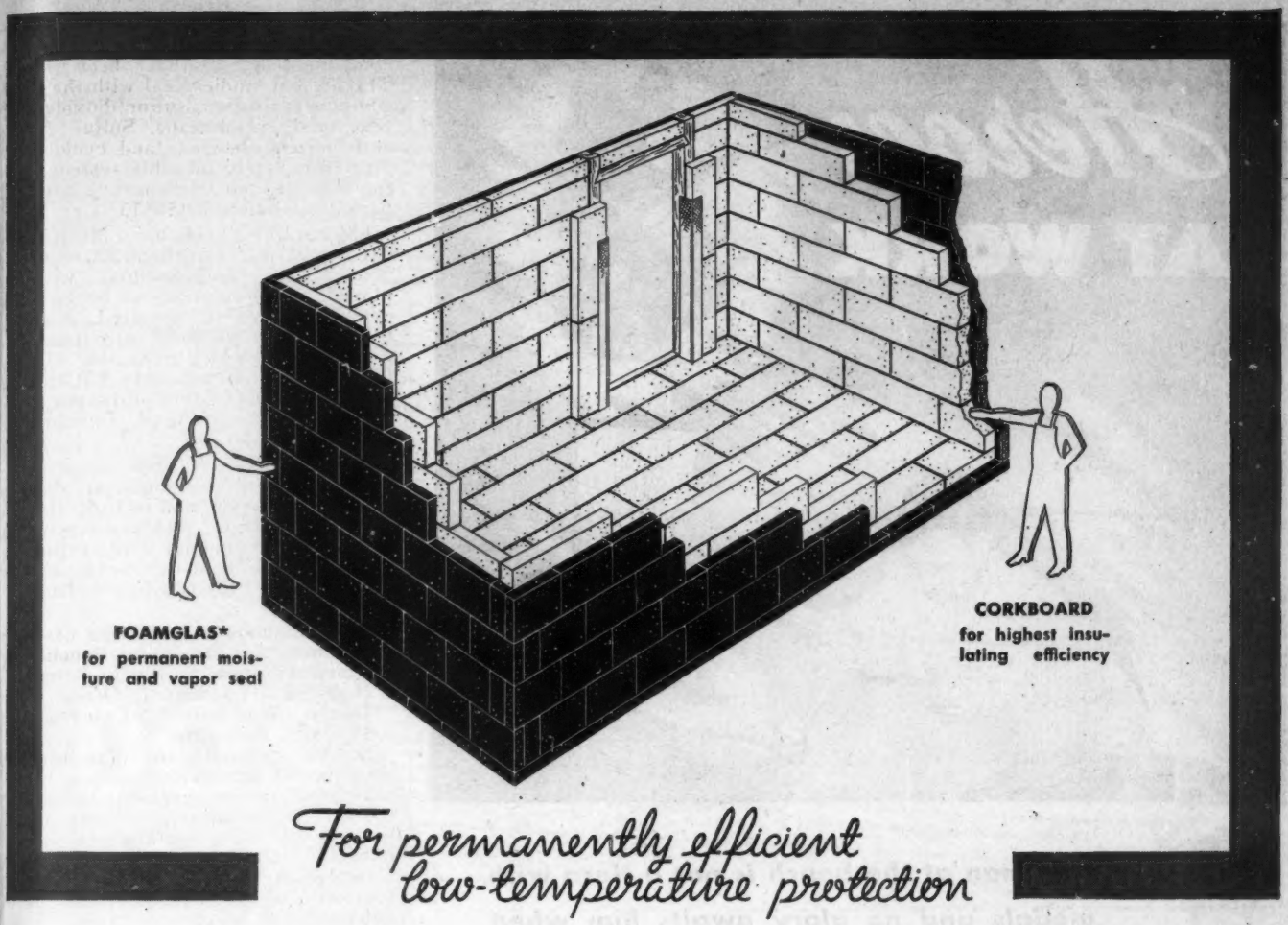
The Discovery and Determination of Neopentane in Refinery Butanes by Infrared Spectroscopy. L. C. Jones, Jr., R. A. Friedel, and G. P. Hinds, Jr., Houston Refinery Research Laboratory, Shell Oil Company, Houston.

Qualitative study of a refinery butane stream by infrared spectroscopy has established the presence of a small amount of neopentane, although this hydrocarbon has seldom been reported. Quantitative determinations show that neopentane occurs in many straight-run butane streams and also in the proper fractions of both East and West Texas crudes.

The reference spectra upon which the qualitative analyses were based and a quantitative method for the analysis of the system propane, *n*-butane, isobutane, neopentane, and isopentane are presented.

The Three-Component System, Sulfur Dioxide, Benzene, and Cyclohexane. Wm. F. Seyer and J. E. R. Lawley, University of British Columbia.

Liquid sulfur dioxide is used exten-



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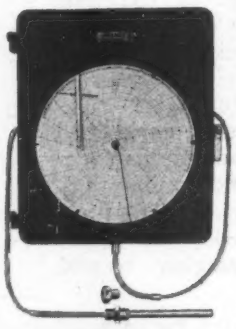

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sively as an extraction medium in the refining of petroleum oils. Numerous two-component systems have been studied. The present studies deal with the three-component system, sulfur dioxide, benzene, and cyclohexane. Sulfur dioxide and benzene, benzene and cyclohexane form completely miscible systems. Sulfur dioxide and cyclohexane are only partially miscible below 13° C.

Since sulfur dioxide has a much higher vapor pressure than the other two components, the "bulb method" was employed. Seven solutions of benzene and cyclohexane were prepared. Weighed portions of these were introduced into glass bulbs to which were added definite quantities of sulfur dioxide. The freezing points and temperature of disappearance or reappearance of the two liquid phases were noted.

From the curves obtained, a three-dimensional three-component diagram was drawn. From this in turn, the isotherm at —25°C. was constructed. A method was found for constructing the lines without actually measuring the composition of the two liquid phases.

The Continuous Introduction of Small Amounts of Gases to Bench-Scale Units. Herman S. Bloch, Alfred E. Hoffman, Thaddeus J. Oleszko, and Joseph A. Chenicek, Universal Oil Products Company.

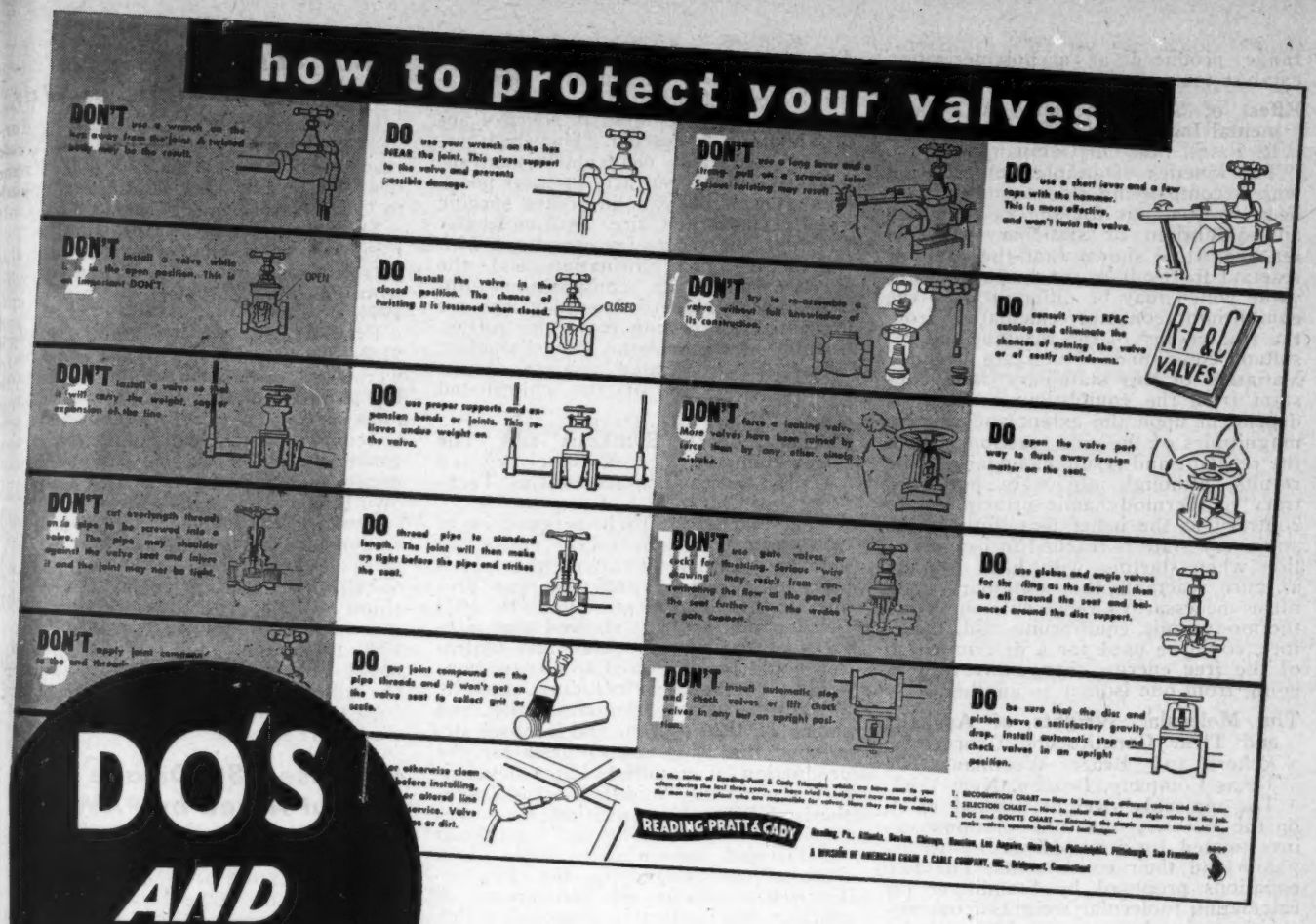
Several methods are described for continuously introducing gases to bench-scale catalytic pressure units in amounts too small to be metered by conventional means. Of these methods, the most flexible is a system of capillary feeds whereby any number of gases may be supplied in such small quantities at independently controlled and variable rates.

Production of Heptenes and Heptanes From Propylene and Butylenes. V. N. Ipatieff and R. E. Schaad, Universal Oil Products Company, Chicago.

Mixed polymerization of approximately equimolecular mixtures of propylene and isobutylene, in contact with solid phosphoric acid catalyst at 135° C. and 45 atmospheres' pressure yielded polymers containing 45 to 60 percent by volume of mixed heptenes and octenes, the latter consisting mainly of diisobutylene. The heptenes were hydrogenated catalytically to heptanes of 89.4 to 90.4 octane number, the latter value being increased to 98.5 by the addition of 1.0 cc. of tetraethyllead per gallon. The heptane fractions contained a high percentage of 2,3-dimethylpentane as shown by physical constants and Raman spectra determinations. The heptane fraction also contained small amounts of 2,2- and 2,4-dimethylpentanes.

In the presence of 50 percent butane, equimolecular mixtures of propylene and isobutylene were polymerized at 135° C. and 45 atmospheres' pressure in the presence of solid phosphoric acid catalyst to give approximately the same yields and types of polymers as were produced from the olefin mixture not diluted by butane.

Polymers formed at 191° C. in the presence of solid phosphoric acid from mixtures of propylene and normal butylenes, present in the approximate molar proportions of 3:1, yielded hydrogenated 150° C. end-point fractions of 56 to 62 octane numbers. These octane numbers were about the same as those obtained by hydrogenating propylene polymers of the same general boiling


how to protect your valves
DON'T use a wrench on the hex near the joint. A twisted pipe may be the result.
DO use your wrench on the hex NEAR the joint. This gives support to the valve and prevents possible damage.
DON'T use a long lever and a strong pull on a screwed valve. Serious twisting may result.
DO use a short lever and a few taps with the hammer. This is more effective, and won't twist the valve.
DON'T install a valve while in the open position. This is an important DON'T.
OPEN
DO install the valve in the closed position. The chance of twisting it is lessened when closed.
CLOSED
DON'T try to re-assemble a valve without full knowledge of its construction.
DO consult your RP&C catalog and eliminate the chances of ruining the valve or of costly shutdowns.
R-P&C VALVES
DON'T install a valve so that it will carry the weight, sag or expansion of the line.
DO use proper supports and expansion bends or joints. This relieves undue weight on the valve.
DON'T force a leaking valve. More valves have been ruined by forced than by any other single mistake.
DO open the valve part way to flush away foreign matter on the seat.
DON'T cut overlength threads on the pipe to be screwed into a valve. The pipe may shoulder against the valve seat and injure it and the joint may not be tight.
DO thread pipe to standard length. The joint will then make up tight before the pipe end strikes the seat.
DON'T use gate valves or cocks for throttling. Serious "wire drawing" may result from constricting the flow at the port of the seat further from the wedge or gate, causing
DO use globes and angle valves for the throttling as the flow will then be all around the seat and balanced around the disc support.
DON'T apply joint compound to the end threads.
DO put joint compound on the pipe threads and it won't get on the valve seat to collect grit or scale.
DON'T install automatic stop and check valves or lift check valves in any but an upright position.
DO be sure that the disc and piston have a satisfactory gravity drop. Install automatic stop and check valves in an upright position.
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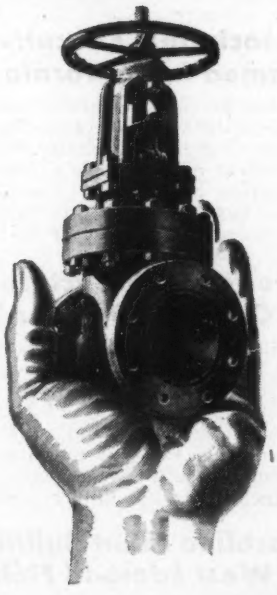

This is the third of the series of charts developed by Reading-Pratt & Cady as a service to the valve users of the nation. Like the other two—How To Know Valves and How To Select Valves—this one, How To Protect Your Valves, will serve as a reminder to experienced men and as invaluable information to new men in industry. It tells in pictures and simple, non-technical language how to avoid the mistakes that shorten the life of valves—how to get maximum service from them.

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range produced at a polymerization catalyst temperature of 205° C.

Effect of Side Reactions on Experimental Isomerization Equilibria. John R. Bates, Sun Oil Company.

The kinetics of simple isomerization with accompanying side reactions have been worked out for the cases where an equilibrium or stationary state is reached. It is shown that the ratio of reactant to resultant reaches a constant value which may be different from the equilibrium constant calculated from the free energy of the reactant and resultant compounds which are isomers. Variation of this stationary state constant from the equilibrium constant is dependent upon the extent and relative magnitudes of the side reactions which the reactant and resultant undergo. The results, although obviously not contrary to thermodynamic principles, are contrary to the belief that if the same stationary state is reached in isomerization when starting with both isomers as pure reactants this stationary state must necessarily represent the true thermodynamic equilibrium and, therefore, could be used for a determination of the free energy change involved in going from one isomer to another.

The Molecular Weights of Asphalts and Their Constituents. George W. Eckert and Bruce Weetman, The Texas Company, Beacon, New York.

The molecular weight method based on the viscosity of dilute solutions was investigated for its applicability to asphalts and their constituents. The two equations proposed by Staudinger for calculating molecular weights from viscosities of solutions can be used for these materials. The constants in the equations were evaluated by using cryoscopic molecular weights of oil and resin fractions ranging in molecular weight from 370 to 900. Viscosities of benzene solutions were determined at 77° F. in a capillary viscometer. The viscosity method appears to be more satisfactory than the cryoscopic method for asphaltenes. The viscosity method gives lower molecular weights than the cryoscopic method for asphaltenes. Values of 700 to 1800 were obtained.

Preparation and Physical Properties of Chlorinated Kerosene. Raymond M. Dean and Eugene Lieber, Standard Oil Company of New Jersey, Bayonne.

The chlorination of petroleum hydrocarbons and their utilization in the chemical arts are becoming increasingly important and have received considerable impetus in recent times. While both the physical and chemical properties of the chlorinated products of the lower molecular weight fractions have been extensively studied and recorded in the literature, not much can be found for the heavier fractions of petroleum. While lack of knowledge of the exact chemistry of chlorination of the higher petroleum fractions has not exactly impeded their present industrial applications, it is generally agreed that such data would very materially broaden their scope. On the other hand, lack of physical data does markedly impede progress in this field, since such data are needed for plant design and control of operation for the chlorination procedure. There has been no systematic study reported correlating the physical properties of chlorinated kerosene with degree of chlorination. It is the object of the present paper to present such a study for a kerosene fraction boiling between 348° and 525° F. and having a low aromatic content (high "furfural miscibility temperature") and chlorinated from 5 to 60 percent chlorine content in steps of approximately 5 percent. The measurements comprise: elementary analysis, refractive index, surface, furfural point, kinimatic viscosity, solid points, specific gravity, flash and fire, and molecular weights. These data are correlated with the degree of chlorination and the average molecular compositions obtained. A number of derived values are presented comprising molecular refraction, molecular volume, and Parachor. These are correlated against atomic chlorine contents of the chlorinated products.

Fischer-Tropsch Synthesis and The Gas Industry. V. I. Komarewsky and C. H. Riesz, Institute of Gas Technology, Chicago.

The Fischer-Tropsch process is of great potential value to the entire gas industry because it offers the possibility of converting off-peak gas production to valuable products. In 1923 Fischer and Tropsch showed that mixtures of carbon monoxide and hydrogen could be converted to oxygen-containing compounds, including aliphatic alcohols, aldehydes, ketones, acids, and esters. In 1926 Fischer and Tropsch developed the Kogasin synthesis for the production of gasoline. Later developments were the "middle-pressure" synthesis (1936), high melting wax synthesis (1938), "naphthene" synthesis (1941), and isosynthesis (1941). Difficulties encountered in the Fischer-Tropsch synthesis are enumerated. A reaction mechanism is proposed which postulates that the function of the catalyst is to provide a hydrogenating-polymerizing surface. Thus, carbon monoxide is converted to methylene at the catalyst surface (hydrogenation) whereas the formation of polymethlene fragments (polymerization) leads to hydrocarbons containing more than one carbon atom. Poisoning of the catalyst by sulfur is explained on the basis of this mechanism. The Fischer-Tropsch process can be utilized by the gas industry if investment costs for the process can be lowered, if a gaseous or readily gasified product is made for enrichment purposes, or if valuable materials can be produced. Research objectives leading to one or more of the above aims are outlined.

Jersey's Operations At All-Time High

Standard Oil Company (New Jersey), reporting operations for the first quarter of 1944, reveals refining plants of its subsidiaries throughout the world processing 1,026,152 barrels of crude oil daily. This is 13 percent above the yearly peak reached in 1941, and compares with 163,000 barrels daily processed in 1918 for the other war. Plants of the company's group in the United States showed an increase of 25 percent above the previous high.

Production of crude oil by the Jersey group was shown at 850,000 barrels daily. In 1941 production was 711,000 barrels daily, the previous peak. Most of the increase is in the United States, where the company's subsidiaries have increased production more than 60 percent.

Further increases in both refining and production have been made since the first quarter, in line with the general stepping up of the industry.

Lend-Lease Oil Reveals Stepped-Up Tempo of War

Lend-lease exports of petroleum during the four months ending with June reached a value of $266,399,000, President Roosevelt disclosed in his report to Congress on lend-lease operations.

Shipments during the four-month period were more than a third of all the petroleum shipped to the Allied Nations from March 11, 1941, to February 29, 1944.

From March, 1941, through June, 1944, $1,009,399,000 of petroleum products were sent to our allies under lend-lease, but pointed out that this "was less than nine percent of total production of petroleum products, and much of the gasoline and oil we have sent abroad under lend-lease has been used by our own forces."

Among the petroleum-consuming equipment lend-leased since March, 1941, were 30,900 planes, 26,900 tanks and 637,600 other military vehicles, 511 cargo ships of 1000 gross tons or over, 1284 merchant and auxiliary craft of under 1000 gross tons, and more than 1400 naval vessels of all types. In addition, the allies have purchased 7000 planes, 1600 tanks and 270,000 trucks for cash, the report showed.

Increased 80-Octane Output Asked by PAW

PAW is calling on refiners to step up output of 80-octane gasoline to the maximum extent possible without interfering with the 100-octane program.

The shortage of 80-octane, which powers the motorized forces engaged in campaigns around the world, results from the stepped-up tempo of military operations in Europe and the expanded 100-octane production. Due to the shortage of aviation base stocks for blending, 91-octane is being stepped up to 100-octane, being replaced by 87-octane gasoline which, in turn, is replaced by 80-octane.

Association Executive Named in California

Don E. Gilman, former vice president and western executive of the Blue Network Company, became executive vice president of California Oil and Gas Association September 1, and D. S. Kilgour has been promoted from assistant secretary to secretary of the association.

Grease Manufacturers Meet In Chicago, October 23-25

National Lubricating Grease Institute has announced its twelfth annual meeting to be held at Edgewater Beach Hotel, Chicago, October 23-24-25. Preliminary anouncement indicates a program of interest to both manufacturers and consumers of grease, prominent speakers to include Army and Navy personnel.

Gasoline Plant Building In West Edmond Field

Peppers Gasoline Company is building a natural-gasoline plant in the West Edmond area, Oklahoma, to process 10 million feet per day. Part of the gathering system already has been laid. West Edmond, limits as yet undefined, is the omst active and prolofic oil field in Oklahoma for several years. Present limits include portions of three counties.

Proposed Postwar World Oil Pact Faces Much Criticism; Senate Must Ratify

Planned eventually to be a world-wide compact for postwar oil production and distribution, an agreement was signed in Washington August 8 between United States and British government representatives, laying down broad principles to be followed in development of world oil resources. Individual applications to specific territories and operations will be handled by a joint commission proposed to be set up. The commission will be empowered only to make recommendations which the two governments could or not as they see fit pass on to their nationals. Given full support of the governments, the commission could well become the machinery for controlling all oil activities in the world. Collaboration of other countries is to be sought.

Adoption of the agreement followed two weeks of conferences between representatives of the two countries, working on recommendations developed in meetings of technical groups last April.

Executives of several American oil companies having international interests have expressed satisfaction with the agreement, but members of the United States Senate are skeptical and an investigation by a special committee is pending.

Up to Senate

That the pact is not of such nature as to require the ratification of the Senate was dispelled by President Roosevelt's announcement on August 24 that the agreement must be formally submitted for Senate approval.

It was indicated that Senate action will be delayed until after the November election.

This stand is in contrast to Great Britain's handling of the agreement. Lord Beaverbrook, who signed for Britain, bound his government without a check from the legislative branch.

J. Howard Pew, president of Sun Oil Company, in a letter to Senator Tom Connally of the Senate foreign relations committee, spearheaded the fight which the American oil industry is expected to make against the proposed international regulations. Pew charged that the pact was written so vaguely that it "already seems to have lulled many into complacency regarding its possible implications," and asserted that "the language is an innocuous or as vicious as its administrators desire to make it." Pew predicted that acceptance of the pact by the United States would "mean establishment of postwar federal regulation of the petroleum industry in this country."

Meanwhile, American oil company executives prepared to insist that the United States industry be adequately represented on the eight-man joint commission which will prepare the recommendations that are more or less assured of adoption by the two governments.

The executives feel that unless American oil interests act as a unit to gain proper representation, all four American representatives on the commission will be selected from the staffs of government departments or agencies. This would assure postwar continuance of government control of the industry without proper recognition of the rights and well-being of private enterprise, they believe.

It is an open secret that the British government will name three men from the industry and one from government to act for their nation on the all-powerful commission, and American oil leaders believe this country should follow the same procedure.

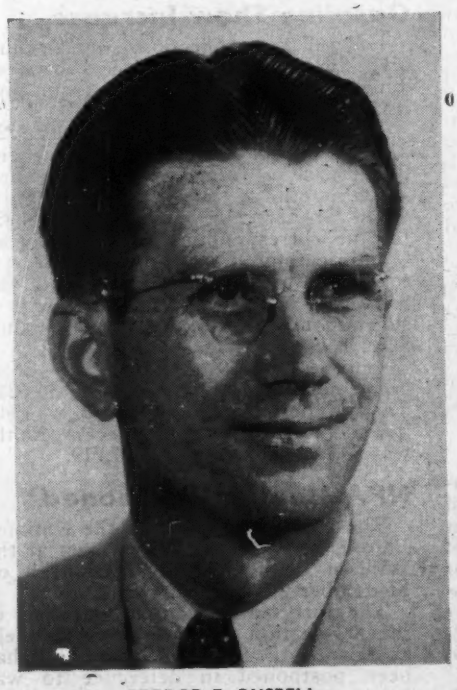
Bradley Dewey Gets Medal

Bradley Dewey, in recognition of his work in coloid chemistry, especially pertaining to rubber latex, and his accomplishment in directing the synthetic-rubber program, has been selected by the American Section of the Society of Chemical Industry to receive the Chemical Industry Medal for 1944.

After studying at Harvard and Massachusetts Institute of Technology, Dewey became director of research for American Sheet & Tin Plate Company in 1911, and in 1919, with Charles Almy, organized Dewey & Almy Chemical Company. Called to Washington soon after Pearl Harbor as assistant in the synthetic-rubber program, he succeeded as Rubber Director upon resignation of William M. Jeffers. Having completed the work of the rubber program, he resigned his government job September 1 to return to his private work as president of Dewey & Almy Chemical Company.

Russell to Oklahoma U.; Gas Drying Research Planned

George F. Russell has been appointed assistant professor of chemical engineering at Oklahoma University, where he will continue research in problems related to fractionation of petroleum and dehydration of natural gas. He has been with the natural gasoline department of Phillips Petroleum Company for the past five years.



GEORGE F. RUSSELL

The university is undertaking a research project on the drying of gases by activated alumina, from a chemical engineering point of view. The investigation which is financially supported by the Aluminum Company of America, is under the direction of Dr. R. L. Huntington, chairman of the School of Chemical Engineering. He will have the part-time assistance of Russell and Blankenship.

U. S. Refinery Output At All-Time High Level

Record runs to stills have brought all-time peaks in the rate of manufacturing refined products in recent weeks.

Crude-oil runs to stills during the four weeks ended August 26 averaged 4,620,000 barrels daily, not quite as high as the 4,632,000 barrels daily in July, but 938,000 barrels greater than the average in August, 1943. During the week ended August 26, crude runs to stills averaged 4,698,000 barrels. The all-time peak in runs to stills is 4,752,000 barrels, established during the week ended June 17, 1944. In numerous recent weeks crude runs have exceeded crude production, which has necessitated heavy drafts on crude stocks.

Production of gasoline during the four weeks ended August 26 averaged 1,990,000 barrels daily, roughly the same as in July. During the past three months gasoline production has been above 2 million barrels daily in about half the weekly periods. Stocks of gasoline totaled 80,740.000 barrels on August 26, about 2 million less than a month ago, but 9 million barrels above a year ago.

Production of residual fuel oil, for which there is a very heavy demand due to naval activity, averaged 1,232,000 barrels daily during the four weeks ended August 26, compared with 1,265,000 barrels during July. Stocks of residual fuel oil stood at 59,339,000 barrels on August 26, up 3 million from a month ago, but 8 million below a year ago.

Distillate fuel oil production was 690,000 barrels daily during August, the same as in July. Stocks of this product totaled 41,543,000 barrels on August 26, or 4 million more than a year ago.

Production Also at Peak

United States production of crude oil during the four weeks ended August 26 averaged 4,670,000 barrels daily, 70,000 barrels more than in July. A new all-time high was established during the week ended August 19, when production averaged 4,690,000 barrels per day. During prewar 1941, the United States produced 3,842,000 barrels daily.

Texas produced 2,109,000 barrels daily during four weeks ended August 26, compared with 2,067,200 during July and 1,615,000 barrels a year ago. Much of Texas' increase during the past year has been in West Texas, now producing 463,000 barrels daily in contrast with 245,000 barrels a year ago. The East Texas field continues to hold steady around 371,000 barrels daily. The Upper Coast, which produced 413,000 barrels per day a year ago, produced 535,000 barrels daily in August.

Daily crude oil production of other important states during the four weeks ended August 26 and change from a year ago are given below:

California 860,000 barrels, up 100,000 barrels; Oklahoma 340,000 barrels, no change; Illinois 207,500, down 11,000;

Louisiana 362,000, up 15,000; Kansas 270,000, down 35,000; New Mexico 108,000, up 5000; Wyoming 93,000, down 7000; Arkansas 80,700, up 3500; Michigan 52,500, down 5000; Pennsylvania 38,325, no change; Mississippi 46,000, down 7000.

The nation's newest oil state, Alabama, produced 200 barrels daily.

Natural Gasoline Output Hits New High in June

Production of natural gasoline and allied products hit a new record in June with an average daily output of 11,462,000 gallons, compared with 11,214,000 gallons in May and 9,873,000 gallons in June, 1943, it was anounced by the Bureau of Mines. Output for the first six months of the year aggregated 2,004,576,000 gallons against 1,792,140,000 gallons in 1943.

Production of light products during the half-year increased in all categories except benzol, which remained constant, and liquefied refinery gas, in which a slight decline was recorded.

Included in the January-June production were 1,062,684,000 gallons of natural gasoline against 963,480,000 gallons last year; 389,046,000 gallons of cycle products against 330,960,000; 104,454,000 gallons of iso-butane at natural gasoline and cycle plants against 76,062,000; 448,392,000 gallons of other liquefied petroleum gases at natural gasoline and cycle plants against 421,638,000; 80,346,000 gallons of liquefied refinery gas at refineries against 84,588,000 gallons, and 50,400,000 gallons of benzol, no change.

Total stocks of natural gasoline and allied products increased by 1,722,000 gallons during June, those at refineries increasing from 89,208,000 to 98,616,000 gallons to offset a decline in stocks at plants and terminals from 97,104,000 to 89,418,000 gallons, the bureau annouced.

On Stream Without Benefit of Ceremony

When the new 100-octane-gasoline facilities of The Texas Company went on stream at Wilmington, California, August 31, the customary ceremonies were absent. Operating personnel of the plant opened the valves, threw the switches and the $20,000,000 project began turning out fuel for the armed forces.

Among the new units completed in 12 months are a fluid catalytic cracking unit and an alkylation plant. An additional crude still was added, also increased fractionation facilities, more steam capacity as well as tankage and pumping facilities.

The new facilities give the Wilmington plant daily charge capacity of 42,500 barrels, from which it can produce 10,000 barrels of 100-octane aviation gasoline and an additional 2000 barrels of other military gasoline.

Plant to Make Paint Ingredient from Oil

Oronite Chemical Company, subsidiary of Standard Oil Company of California, will build a new plant at Richmond for the manufacture of phthalic anhydrite, a basic stock for alkyd resin paints and finishes. The announcement made known that the company will make no finished paint products but will furnish the basic chemical to manufacturers.

Phthalic anhydrite is made by the oxidation of naphthalene and has other possible uses, one of which was described in the Oronite release as "the starting material for the manufacture of one of the new insect repellants which have been so important in maintaining the health of American fighting men in the South Pacific. Studies are being made to extend its uses to other chemical fields."

The plant will cost $1,000,000 and work will start within 30 days. The project has been approved by the War Production Board.

Bead TCC Catalyst Plant in Operation

The first catalytic cracking plant east of the Rocky Mountains to use the bead type catalyst has been put in operation by Socony-Vacuum Oil Company at Paulsboro, New Jersey. The unit is a typical TCC installation except that it provides for the use of catalyst in bead form rather than the pellets common to early TCC units.

Gas Institute Completes Gasification Laboratory

A new gasification research laboratory has been built for the Institute of Gas Technology, Illinois Institute of Technology, Chicago.

The laboratory, which adds 30 percent to the space available for gas industry research, was ready September 1. Though the structure will be used primarily for gasification research, a portion will be utilized as an addition to the Gas Institute library.

The laboratory bridges the space between two present buildings of the Gas Institute, and the structure will accommodate 20 research workers.

East Texas Plant Reopened

Danciger Oil & Refineries, Inc., has reopened its East Texas skimming and cracking plant after a 4-year lapse, and will process 200,000 barrels monthly. The plant was restored to production by PAW, which arranged for Humble Pipe Line Company to supply the oil.

U. S. Tax Collections on Gasoline Show Increase

Federal tax collections on gasoline and lubricating oils increased between June and July but receipts from pipe line transportation fell.

July revenue from gasoline was $22,213,653 against $21,028,517 in June and $26,365,208 in July, 1943. For the first seven months of the year, receipts aggregated $147,806,513 against $146,044,839 for the corresponding period last year.

Lubricating oils paid $5,473,271 in taxes against $3,808,507 in June and $4,294,413 in July of last year, with a seven-month total of $32,388,398 against $26,338,707.

Only $1,120,079 came in July from pipe line transportation, against $1,621,370 in June and $1,202,502 in July, 1943, but the total revenue for seven months was $9,161,973 against $7,657,719.

NPA Meeting Postponed

The board of trustees of the National Petroleum Association will meet at the William Penn Hotel in Pittsburgh on September 29.

The forty-second annual meeting of the association which was to be held at Atlantic City on September 20-21 has been postponed in deference to war travel conditions.

Howard Marshall Quits As PAW General Counsel

J. Howard Marshall, general counsel of PAW since the early days of OPC, has resigned to return to law practice at San Francisco.

Marshall was a member of the Petroleum Administrative Board in the NRA period, and joined the Ickes agency in its formative days.

Dene B. Hodges, since January 31, last, assistant director of the supply and transportation division, has resigned to return to Shell Oil Company, for which he was manager of transportation and supplies for the Mid-Continent and Atlantic Coast areas, and Mercer H. Parks, chief of the scheduling and expedition section of the materials division, has returned to the engineering staff of the Humble Oil & Refining Company.

Shell Promotes Border At Wood River Plant

L. E. Border has been named head of the cracking department of the Wood River plant of Shell Oil Company. His connection with the organization began at Wood River as a junior chemist following graduation from Colorado University. Between 1930 and 1940 he had been assistant in the topping department, an assistant department head in the iso-octane plant and a senior technologist.

In 1941 he joined the staff of Shell Development Company as an engineer but returned to Wood River that year as a senior technologist. The next year he became head of the pilot plant in catalytic cracking.

Hilliard Promoted at Shell Houston Plant

Fay Hilliard has been appointed acting head of the utilities department of Shell Oil Company's refining plant at Houston. Following graduation from Rice Institute in 1933 he became a laborer in the engineering department at Houston. He became an engineer in 1936 and two years later was promoted to assistant utilities engineer, a position he held until his recent appointment.

Davidson Advanced by Standard of California

George A. Davidson, who has been assistant general manager of manufacturing, has been elected a vice president of Standard Oil Company of California.

He has been in the organization since 1921, following graduation from the University of California. His first work was in the research department. In 1933 he became superintendent of El Segundo refining plant. He was advanced to assistant general manager of manufacturing in 1943 and earlier this year was appointed an assistant vice president.

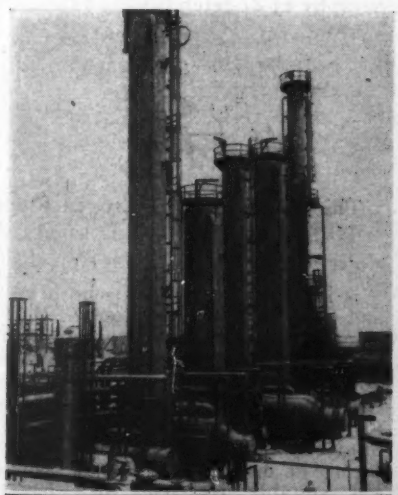
Says Half of Synthetic Rubber Plants to Survive

About half of the plants producing synthetic rubber will be able to survive after the war, largely because their product is superior to natural rubber for some purposes, Col. Bradley Dewey, retiring rubber director, said last week.

Predicting that American chemists will develop still better synthetic rubbers, Dewey pointed out that synthetic tires, except in the larger sizes, already are better than all except top-quality prewar tires from natural rubber.

If yours is one of more than 200 refineries not now participating in the 100-octane program for war, you should and will be interested in how expertly we can help you overcome obsolescence . . . our facilities . . . our experience . . . the fact that repeat business has constituted 60% of our contracts during the last six years.

We serve the industry that makes possible all modern modes of transportation.



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The abstracts here presented are selected from the current literature of science and technology to afford reference to fundamental information not easily available to all readers. Abstracts of articles appearing in readily obtainable trade journals are not included.

Photostat copies of original articles will be supplied at cost by the Leslie Laboratories. Complete or limited bibliographies covering special topics by title, by abstracts, or in complete manuscript, will also be prepared and furnished at reasonable cost by the Laboratories.

Fundamental Physical And Chemical Data

Correlating Vapor Pressure and Equilibrium Constant Data. D. F. OTHMER. *Ind. & Eng. Chem.* **36** (1944) pp. 669-72.

In previous articles the author has presented a logarithmic plot of vapor pressure or related pressures of a compound correlated against the pressures exerted by a reference substance at the same temperature, and has used this procedure to correlate data for vapor pressures, latent heats, heats of chemical reaction, gas solubilities, heats of solution, adsorption equilibrium pressures, heats of adsorption, and other properties. It appears that the same procedure might be a useful tool for correlating values of the so-called equilibrium constant, K, used in the design of distillation, absorption, and related systems involving particularly hydrocarbons, such as petroleum fractions. Data for equilibrium constant K are correlated by a logarithmic plot against vapor pressure of a reference substance at the same temperatures to give substantially straight lines. A nomogram has been prepared based on this correlation that gives K values for the hydrocarbons below nonane at different pressures and temperatures in a form that is useful when constant K values are to be compared. A second nomogram is presented that is useful for obtaining K values for hydrocarbons in this range at the same temperature and pressure as would be necessary, for example, in plate-to-plate calculations of a distilling column handling hydrocarbons.

Phase Equilibria in the System Ethane-Ethylene-Acetylene. J. L. MCCURDY AND D. L. KATZ. *Ind. & Eng. Chem.* **36** (1944) pp. 674-680.

In studies of hydrocarbon phase behavior, binary mixtures of acetylene and ethane and acetylene and ethylene have been shown to form constant-boiling mixtures under pressure. Since mixtures of these gases result from high-temperature cracking processes and are present in hydrocarbon mixtures during separation, the vaporization characteristics are of particular interest. Acetylene has been found to have vaporization tendencies differing from those that would be predicted by the position of its vapor pressure curve as related to the vapor pressure curves of other hydrocarbons. The ethane-ethylene-acetylene ternary system was chosen for study since two of the binary systems are known to form constant-boiling mixtures, and the third, ethane-ethylene, has been shown to be of the normal type. The phase equilibrium relations of the ethane-ethylene-acetylene system were studied at two temperatures, 40° and 60° F., and at a series of pressures in 50-pound intervals covering the entire two-phase region at each temperature. The constant-boiling mixtures of the ethane-acetylene and ethylene-acetylene systems persist through the triangular three-component diagrams. At constant temperature and pressure these diagrams have two two-phase areas. Acetylene is the most volatile component in one area and the least volatile in the other area. The apparatus used in the work is described in some detail and the method followed is given. Data are presented in considerable detail in tabular form and the phase diagrams are presented in graphical form. A bibliography of 27 references is appended.

Chemicals Wanted

The National Registry of Rare Chemicals, Armour Research Foundation, Thirty-third, Federal and Dearborn Streets, Chicago 16, Illinois, has received urgent requests for the chemicals listed below. If anyone has one or more, even if only in one gram quantities, please inform the registry.

Alkyl substituted ethylene and propylene oxides.
Carbon tetraiodide.
Cerotic acid.
Carbon oxy sulfide.
1,2-Dihydroxy anthracene.
Unsym. dichloro succinic acid.
1,1-Dimethyl glycidol.
1,3-Epoxy propane.
1-Methyl-1-phenyl glycidol.
Ethyl or methyl-n-octyl amine.
Ethyl or methyl-n-decyl amine.
Ethyl or methyl-n-dodecyl amine.
Formamidine hydrochloride.
Formyl urea.
Beta, gamma-dimethyl allyl alcohol or any halide.
Hexabrom ethane.
Normal aliphatic primary amines of 7,9,15,19-29 carbons.
Octachloro-n-propane.
2,4-Pentadiene-l-ol.
Sodium isethionate (100 grams).

The Viscosity of Hydrogen Fluoride. J. H. SIMONS AND R. D. DRESDNER. *Jour. Amer. Chem. Soc.* **66** (1944) pp. 1070-72.

It is well known to all who have used and handled hydrogen fluoride that it is a material of high fluidity. The increasing use of this substance adds to the importance of knowing its physical properties accurately. To date no measurements of the viscosity of hydrogen fluoride have been recorded in the literature. The usual laboratory viscometer is not suitable for use with hydrogen fluoride because of its reaction with glass. The authors measured the viscosity of pure hydrogen fluoride, commercial hydrogen fluoride, and hydrogen fluoride containing a small percentage of ethyl alcohol over the range of temperature from approximately —70 to above 0° C. Hydrogen fluoride has a viscosity not greatly different from that of ethyl ether at the same temperature. Small amounts of impurities such as water and ethyl alcohol tend to increase the viscosity markedly. The apparatus used in making the determinations is described in some detail and the procedure used is

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As a case in point, the *Foxboro Hyper-Reset Stabilog Controller* has brought to air-operated control a degree of high performance that has never been approached. Operating on a principle entirely different from previous standard controllers, this remarkable instrument "feels" the rate of change of disturbance at the very start. Corrective action, measured and of the proper magnitude for any adjustment or disturbance, is instantly in effect. The result is smoother and faster recovery from any process disturbance. Under average process conditions, recovery is often effected *in as little as one-fourth the usual time – with as much as 50 per cent reduction in the amount of upset.*

In appearance as well as action, too, the Model 30 Stabilog Controller reflects the advanced thinking of Foxboro Instrumentation. Its trim, rectangular housing "squares the circle" for compactness, high visibility, and broad utility. Its modern design permits true flush mounting for maximum efficiency and safety.

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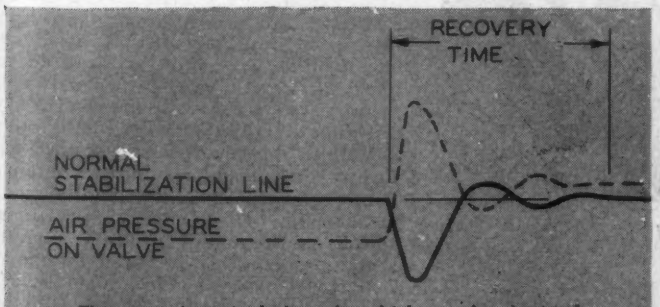
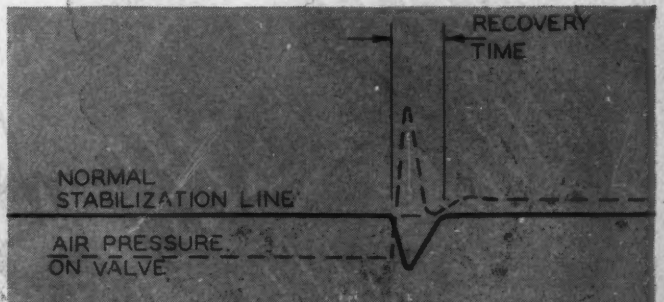


This curve is typical of results which may be obtained from efficient proportional control with reset before the development of HYPER-RESET. Note the period required for recovery from this typical upset.



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given. Data are presented in tabular and graphical form.

Chemical Compositions And Reactions

Catalytic Aromatization of Branched Chain Aliphatic Hydrocarbons. V. I. KOMAREWSKY AND W. C. SHAND. *Jour. Amer. Chem. Soc.* **66** (1944) pp. 1118-19.

The authors studied the mechanism of the reaction by which aliphatic hydrocarbons are transformed into aromatics. They were particularly interested in studying the question as to whether aromatization of paraffins goes through the intermediate step of naphthene formation. With this in mind, the following aliphatic hydrocarbons were subjected to the action of chromia on alumina catalyst: 2,2-dimethylhexane, 2,2-dimethylhexene-3 and 2,2-dimethylheptane. The experimental work is described and the results are presented in tabular form. It was concluded that aliphatic hydrocarbons, containing a quaternary carbon atom that does not permit direct aromatization, dehydrocyclize with the production of aromatics in the presence of chromia-alumina catalyst. This indicates that isomerization takes place during dehydrocyclization. Aliphatic hydrocarbons the structure of which permits cyclization in more than one way, dehydrocyclize to aromatics by means of a mechanism that permits their direct formation.

Chemistry of Sulfur-Olefin Reactions. R. T. ARMSTRONG, J. R. LITTLE, AND K. W. DOAK. *Ind. & Eng. Chem.* **36** (1944) pp. 628-33.

The chemistry of the sulfur vulcanization of rubber is interpreted in terms of reactions of simple mono-olefin analogs with vulcanizing ingredients. 2-Methyl-2-butene, the analog of rubber, forms principally a mixture of dialkenyl mono- and disulfides, symmetrical and unsymmetrical, containing the following structural units: B-methylcrotyl, a,B-dimethylallyl, and y-methylcrotyl. 2-Methyl-1-butene forms a similar mixture of mono- and disulfides, containing B-methylcrotyl and B-ethylallyl structural units. Di-(B-methylcrotyl)monosulfide is the major product from the reactions of both 2-methyl-2-butene and 2-methyl-1-butene. The formation of a,B-dimethylallyl unit from 2-methyl-2-butene, and of B-methylcrotyl unit from 2-methyl-1-butene indicates that a free radical of the allylic type may be an intermediate in the reaction. 2-Butene, the simplest analog of butadiene polymers, forms dicrotyl sulfide and nonvolatile products. By analogy it is concluded that sulfur vulcanization of rubber is due chiefly to the formation of disulfide and monosulfide cross links that are attached to the a-methylene groups or the a-methyl group of the rubber chain. As a consequence of re-

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A-178 Electric Resistance Welded Steel and Open-Hearth Iron Boiler Tubes—intended for boiler tubes, boiler flues, superheater flues and safe ends and is used for heat exchanger and condenser tubing in sizes 2″ O.D. and larger.

Carbon 0.08 to 0.18—minimum wall unless otherwise specified.

A-249 Atomic-Hydrogen-Arc-Welded and Electric-Resistance-Welded Alloy Steel Boiler and Superheater Tubes—intended for boiler tubes and superheater tubes; frequently used for heat exchanger and condenser tubes of the following types: 304, 316, 317, 347.

STAINLESS STEEL CHEMICAL ANALYSES

Type	Carbon	Manganese	Silicon	Chromium	Nickel	Molybdenum	Phosphorus	Sulphur	Others
302	.20 Max.	1.25 Max.	.75 Max.	17.5—20.0	8.0—10.0		.030 Max.	.030 Max.	
304	.08 Max.	2.00 Max.	.75 Max.	18.0—20.0	8.0—10.0		.030 Max.	.030 Max.	
347	.10 Max.	2.00 Max.	.75 Max.	17.0—20.0	8.0—10.0		.030 Max.	.030 Max.	CB = 10xC Min.
309S	.08 Max.	1.50 Max.	2.00 Max.	22.0—26.0	12.0—14.0		.030 Max.	.030 Max.	
316	.10 Max.	1.50 Max.	.75 Max.	16.0—18.0	10.0—14.0	2.0—3.0	.030 Max.	.030 Max.	
317	.10 Max.	1.50 Max.	.75 Max.	18.0—20.0	10.0—14.0	3.0—4.0	.030 Max.	.030 Max.	
442	.15 Max.	.50 Max.	.50 Max.	18.0—23.0			.030 Max.	.030 Max.	
446	.15 Max.	.50 Max.	.50 Max.	23.0—30.0			.030 Max.	.030 Max.	

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arrangement, allylic isomers are possible. Data show that the degree of cross linking of rubber vulcanizates is closely related to the amount of zinc sulfide formed during the reaction.

Manufacture: Processes And Plant

Separation and Recovery of Aromatic Hydrocarbons from Paraffins and Naphthenes by Absorption. B. J. MAIR AND A. F. FORZIATI. *J. Res. Natl. Bur. Stand.* **32** (1944) pp. 165-83 (Res. paper No. 1583).

The solution to be separated is introduced into the top of a column containing an excess of adsorbent. A low-boiling paraffin hydrocarbon is added in quantity sufficient to remove the paraffins and naphthenes but not the aromatics. These are removed by adding a desorbing liquid such as methyl alcohol. The paraffins and naphthenes in solution in pentane can be determined by removing the pentane by distillation. The aromatics are obtained as a mixture with pentane and methyl alcohol. The methyl alcohol is removed by extraction with water and the pentane by distillation. The procedure has been tried on a known mixture of 17 pure hydrocarbons ranging in boiling point from 60 to 174° C. The separation and recovery of the aromatic hydrocarbons is quantitative. Determination can be made of the quantity of aromatics adsorbed per unit quantity of adsorbent using silica gel, carbon, MgO, AL_2O_3, Filtrol and Florisil as adsorbents. The results are presented as adsorption isotherms.

Removal of H_2S by Thylox Process. *Chem. & Met. Pictured Flowsheet, Chem. & Met. Engr.* **51** (1944) pp. 130-33.

A flowsheet is presented for the removal of hydrogen sulphide by the Thylox process. The Ford installation handles over 50,000,000 cubic feet of gas per 24-hour day. Grid-packed adsorbers 22 feet by 90 feet high are used. The absorbing solution contains sodium thioarsenate and is maintained at a proper pH value. The reagent is reactivated in the thionizers in which compressed air bubbles through the fouled Thylox solution. A froth of free sulphur is separated at the top of the thionizers and continuously overflows into a hopper bottom trough to a slurry tank which in turn feeds a rotary filter. The filter cake contains both sulphur and insoluble impurities. It is run to an autoclave for separation. The melted sulphur from the autoclave can be solidified in pan or may be handled by an endless stainless steel belt. At the end of the belt the solidified sulphur is cracked to small pieces which fall into the hopper for final distribution.

Sulphur Removal and Recovery from Coke Oven Gas. N. G. FARQUHAR. *Chem. & Met. Engr.* **51** (1944) pp. 94-6.

Sulphur compounds in coke oven gas have presented a problem of increasing severity at the Rouge plant of the Ford Motor Company at Dearborn, Michigan. Prior to the war approximately 12 million cubic feet of coke oven gas per day were used, and approximately 10 million more cubic feet became necessary with the construction of a magnesium smelter and an armor plate building. It was decided to use the Thylox system which

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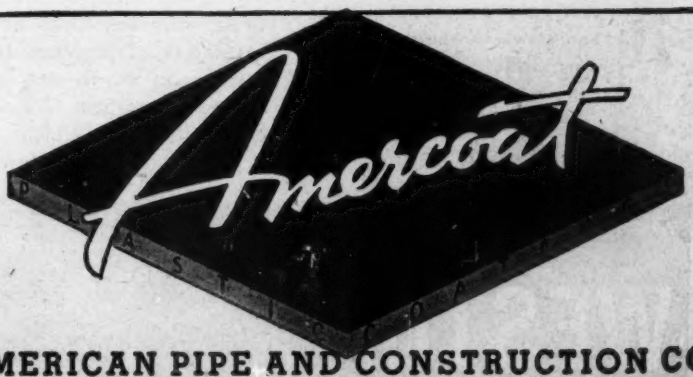

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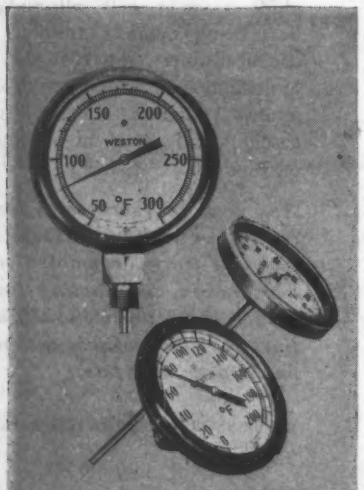

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results in the recovery of the sulphur in elemental form. Approximately 6 tons per day of 99 percent pure sulphur are recovered in the Ford plant. This sulphur in colloidal form can be utilized in the manufacture of fungicides. In the recovery and purification process the gas, practically 100 percent free from tar and ammonia, is brought into contact with a solution of sodium thioarsenate, subsequent air oxidation on the resulting solution frees the sulphur and leaves the solution active for re-use. Approximately 98 percent of the sulphur is removed from the gas.

The Calculation of the Volumes Contained in the Partially Filled Dish Ends of Horizontal Cylindrical Tanks. H. A. BLACKMORE. *Jour. Inst. Petr.* **30** (1944) pp. 167-70.

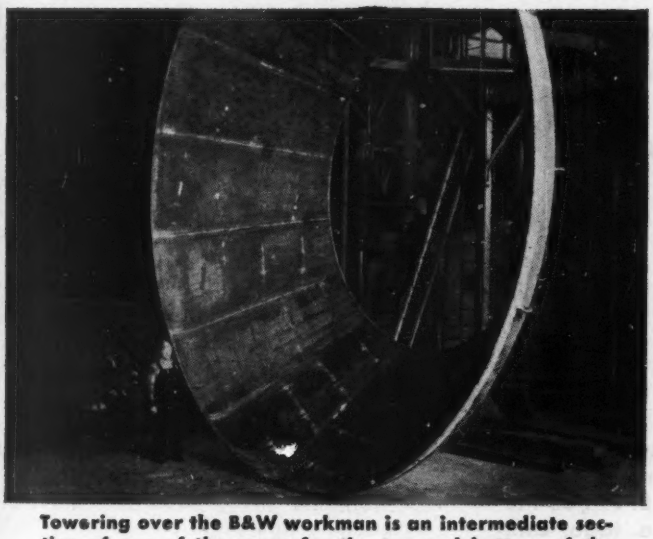
The figures representing the volumes of liquid contained in the dish ends of horizontal cylindrical tanks, except when the tank is full, are formed by the interception of the plane surface of the liquid, an imaginary plane constituting the end of the tank, and the dish end. There are thus three surfaces: two plane and one curved. The angle between the plane surfaces is 90° when the axis of the cylinder is horizontal. Equations are given for the calculation of the volumes of such containers. In practice, however, the heights of the oil in the tanks is gauged so that h is the independent variable and the other variables must be changed into explicit functions of h. However, such a function is intractable and would be useless for ordinary work owing to its complexity. To overcome this difficulty, the author assumes that certain angular functions are substantially invariant with h insofar as these can be measured from a tank blue print. An equation is derived for the volume at any value of h. The equation based on a spherical head proved to give too high results. It was found to introduce a negligible error to assume that the segments are of a paraboloid of revolution. An equation is developed on this basis, and corrections are given for the so-called spherical error involved.

Products: Properties And Utilization

Operating Automotive Equipment at —50° F. R. WAYNE GOODALE. *S. A. E. Jour. (Trans.)* **52** (1944) pp. 276-80.

At the winter temperatures of the far north cetane number is of less importance in diesel fuels than low pour point. Large quantities of stove oil were used as diesel fuel, along the Alaska highway, by various types of engines. A product known as Ban-ice when used in the proportion of 1 percent prevented the freezing of water dissolved in gasoline or diesel fuel at temperatures as low as —50 to —60° F. A relationship was noted between cetane number and the lowest temperature at which a diesel engine will start readily. At 50 cetane number the temperature is approximately 28° F.; at 40 cetane number the temperature is approximately 35° F. However, below 20° F. the difference in cetane number is not important. A starting fluid was used to facilitate engine starting at sub zero temperatures. To overcome difficulty resulting from stiffening of the crankcase oil gasoline was

achievement



Towering over the B&W workman is an intermediate section of one of the cones for the top and bottom of the tower.

NEW problems . . . in design . . . in fabrication . . . in fitting . . . in transportation . . . all had to be solved in supplying a giant alloy-clad reactor tower for a new West Coast refinery. It was the kind of a job that called for ingenuity and originality from start to finish.

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The E. P. Series Air Motor has the extra power needed for fast removal of hard, heavy deposits even in large diameter tubes. Where hard spots stall ordinary motors, the E. P. has the extra torque to cut through. This feature saves time, labor and money in tube cleaning.

The reason for the high torque, extra power and low air consumption of the E. P. Motor lies in its exclusive valve design. Full use of air with minimum back pressure, leakage and friction, together with its six-cylinder construction, provide smooth power and prevent stalling.

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added to the engine oil before stopping. An oil lighter than SAE 80 but with extreme pressure characteristics was used as a gear lubricant.

Special Cold-Starting Fuels for Diesel Engines. G. H. Cloud and L. M. Ferenczi. *Stand. Oil Develop. Co. S. A. E. Jour.* **52** (1944) pp. 233-7.

Ignition quality of diesel fuels is the best index of starting performance. The higher the cetane number the lower the minimum starting temperature for a given engine and lubricant. This, however, does not hold for cetane numbers above 55 to 60. Various ignition promoters were studied including amyl nitrate, isobutyl nitrate, 1,1-dichloro-1-nitroethane, and diamyl trisulfide. Diamyl trisulfide was found to be the most effective and gave an 8° F. lowering of starting temperature. Some of the straight-chain ethers have high cetane numbers and cold-starting tests were made with them. There seemed to be no correlation between cetane number and starting performance. Hexyl ether and n-butyl ether in 25 percent blends gave better performance than would have been predicted. The 25 percent ethyl ether blend was better than either of its components. The optimum concentration of ethyl ether in blends is 40 to 50 percent. At 42:58 ethyl ether reference fuel blend permits starting at a temperature 24° lower than with 74 cetane-number reference fuel and 14° F. lower than with straight ethyl ether. Ethyl ether lowers the cloud and pour points of fuels. Ethyl ether is commonly used in England and most diesel engines are there equipped with an applicator for admitting ether with the entering air during the starting period. The use of ethyl ether in the air stream will allow starting temperatures as low as —40° F. without other starting aids provided the lubricant permits sufficient cranking speed.

Steam Turbine Lubricating Oils. *Lubrication* **30** (1944) pp. 41-56.

Troubles in turbine lubrication are caused by emulsification, foaming, oxidation and sludging occasioned by excess air, water or heat. In turbine oil circulating systems a sufficient capacity is provided to allow an ample rest period before recirculation of the oil. However, there is sufficient turbulence to cause emulsification if the oil emulsifies readily. For the modern high-speed turbine directly connected to an electric generator, oils of two viscosities are commonly made, one of 140 to 170 Saybolt seconds and another of 175 to 250 seconds, at 100° F. When a turbine is geared down as to propeller shafts, an oil of higher viscosity is required in order to lubricate both bearings and gears. For such a purpose the viscosity ranges needed are from 250 to 350 and from 400 to 550 seconds. Foaming, caused by aeration of the oil, impedes the flow of oil to the bearings and causes erratic action of the governor. The conditions causing it are discussed. Oxidation is minimized by careful refining of the oil to remove easily oxidizable compounds. Sludge that develops when a tubrine oil is agitated in the presence of air or water, especially when overheated, is formed in two stages, the colloidal or soluble stage and the insoluble stage, in

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which the sludge becomes permanent. Oil-water emulsions separate readily if the oil is uncontaminated and not oxidized. Several corrosion and oxidation tests are described and their value discussed.

Laboratory and Field Tests on Coal-in-Oil Fuels. J. F. BARKLEY, A. B. HERSBERGER AND L. R. BURDICK. *Trans. Am. Soc. Mech. Engrs.* **66** (1944) pp. 185-98.

The viscosities of suspensions of finely divided coal in heavy fuel oil rise decidedly in the region of 40 to 50 percent of coal by weight and are independent of the viscosity of the oil and of the temperature of the measurement. A rapid increase in viscosity also occurs between coal sizes of 200/230 and 230/325 mesh. The suspensions are thixotropic. A stable suspension can be made by dispersing 40 percent by weight of coal ground to 98/99 percent through a 230-mesh screen. The mixing of the coal and the heavy fuel oil is not difficult. In using the coal-oil suspension about two thirds more atomizing steam is required. Ash trouble is less than when using pulverized coal. Combustion efficiency is somewhat less than that for oil alone. The load-carrying flexibilities of coal-in-oil fuels and oil fuels are comparable. Careful control of storage and handling temperatures is necessary.

Processing Behavior of High Polymers. R. L. ZAPP AND A. M. GESSLER. *Ind. & Eng. Chem.* **36** (1944) pp. 656-61.

The effect of high polymer deformation depends upon the relative amount of high elastic and viscous deformation. In order best to predict processing behavior by plasticity measurement, the relative extent of high elastic and viscous deformation should govern the conditions of test. Since most processing equipment deforms polymers at a rate at which high elastic deformation is prominent, conditions should be established at fairly high rates of deformation to a constant deformation value. If plasticity and elasticity of polymers are determined under these conditions over a temperature range, thermoelastic and thermoplastic differences may be noted that correlate with processing behavior. With butyl rubbers the thermoplastic and thermoelastic curves detect differences in polymer behavior that can be attributed to molecular weight distribution as well as to average molecular weight. These factors not only affect the appearance of butyl extruded specimens, but a ratio of elasticity to plasticity governs the swell after extrusion deformation. The data indicate that a narrower distribution of molecular weight for a given average molecular weight is desirable from a processing standpoint. Perbunan type polymers exhibit greater thermoelasticity than do butyl or natural rubber types. Mill behavior, the most important processing factor for Perbunan types, depends upon this thermoelasticity and its change upon mill breakdown. Plasticity is also important, for laboratory studies appear to show that anomalous milling characteristics can be ex-

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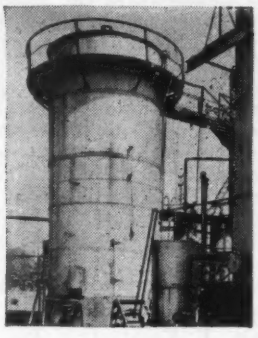


Tellurium Lead resists vibration: In chemical handling equipment subject to vibration, the stresses resulting from the continuous, alternating movement may result in failure of the materials from which the equipment is made.

This breakdown may take the form of a crack in a tank lining or a leak in a heating coil or pipe line.

The service records of users whose statements are in our files show that in a number of instances Tellurium Lead sheet and pipe have given better service under such vibratory conditions than the materials which were previously used.

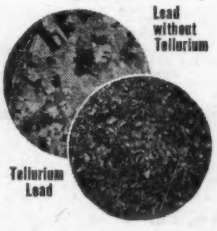
Higher endurance limit: This improved vibration resistance was borne out by a simple laboratory test in a Haigh "fatigue" testing machine. Loads were applied to test strips of lead which were subjected to rapid, repeated stresses simulating vibration. Nearly twice the load was required to fracture a Tellurium Lead specimen as a specimen of lead without tellurium. Among technologists Tellurium Lead's higher "endurance limit" is generally accepted as a measure of its resistance to vibration failure.

☆ ☆ ☆

Tellurium Lead's greater resistance to vibration, as well as its generally superior performance under heat changes, elevated temperatures and stress-corrosion, is believed to result from a combination of the characteristics enumerated below, which distinguish it from lead without tellurium.

1. Strengthens under stress: Tellurium Lead has the ability to "work-harden." Physical stress actually increases its tensile strength and makes it more fracture-resistant than before. For example, these pipes of Tellurium Lead (top) and lead without tellurium (bottom) were stamped with their respective names and pulled out at equal rates in a tensile testing machine. Note how the Tellurium Lead was toughened by the stamping, how it work-hardened and developed strength, whereas the lead without tellurium was weakened—and fractured.

2. More uniform grain structure: Undoubtedly another factor is Tellurium Lead's generally more uniform and finer grain structure as shown in photomicrographs at right. As a result, its surface is smoother—there is less possibility of pitting and local corrosion.



3. Higher recrystallization temperature: Another result of the addition of tellurium to lead is a raising of the recrystallization temperature.

Ordinary lead recrystallizes below room temperature. For this reason the hardness developed in lead by cold "working" is not retained. The grain structure produced by working is not permanent since, as soon as the working ceases, the grains "grow."

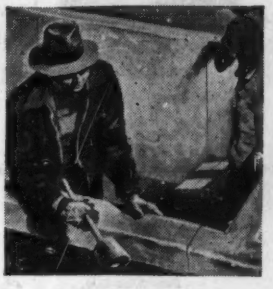
Tellurium Lead recrystallizes at more than 200° F. It thus retains the hardness developed by working and the grains of Tellurium Lead do not begin to "grow" until a relatively high temperature is reached. In laboratory tests, extruded strips of Tellurium Lead, annealed at 150° C. for six months, showed no grain enlargement. This freedom from grain growth at temperatures up to 200° F. is believed to be beneficial both from the standpoint of corrosion resistance and physical strength.

☆ ☆

Where it is used: Tellurium Lead is widely used in contact with sulfuric acid and sulfates, phosphoric acid and chromic acid. It may also be used in contact with pickling, electroplating and other corrosive solutions.

Among the types of chemical operations in which Tellurium Lead is employed are: chlorinations, reaction chambers, reductions, pickling, sulfonations.

Typical installations include: agitators, aprons, drums, ducts, fans, flooring, heat exchangers, heating and cooling coils, kettles, pans, stills, sulfuric acid chambers, table tops, tanks, vats.



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How it is applied: Tellurium Lead may be bent, seamed, flanged, burned, in the same manner as chemical lead.

WHAT USERS REPORT:

"We have installed a number of tank linings using Tellurium Lead. It has been very satisfactory in cases of hot liquor and agitation where in the past some of the upright seams have cracked."

• • •

"Tellurium Lead is used in our chlorinators for bond-coating steel agitators, thermometer wells, chlorine inlet spouts, etc., and is exposed to relatively low concentrations of chlorine and hydrochloric acid gases at 50-75° C. Its rate of corrosion is about half that of ordinary lead."

• • •

"We highly recommend Tellurium Lead for heating and cooling coils. It has also been giving very good service in agitators, saturators, pickling and etching tanks."

TELLURIUM LEAD

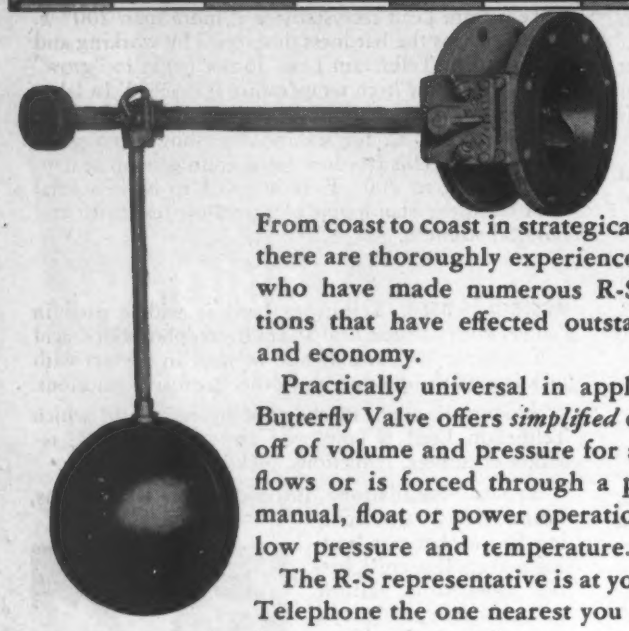
What it is: Tellurium Lead of our manufacture is time-tested St. Joe chemical lead alloyed with a small quantity of tellurium. It gives the advantages of this well-known chemical lead plus important new ones.

Available forms: Tellurium Lead is available in sheet or pipe form or fabricated in coils for heating and cooling purposes.

For further information or advice regarding the use of Tellurium Lead, write:

NATIONAL LEAD COMPANY—New York 6, Baltimore 3, Buffalo 3, Chicago 80, Cincinnati 3, Cleveland 13, St Louis 1. National-Boston Lead Co., Boston 6; John T. Lewis & Bros. Co., Philadelphia 7; National Lead & Oil Co. of Penna., Pittsburgh 12; Georgia Lead Works, Atlanta; American Lead Corp., Indianapolis 6; Master Metals, Inc., Cleveland 13; Morris P. Kirk & Son, Inc., Los Angeles, Calif. The Canada Metal Co., Ltd., Toronto, Montreal, Winnipeg, Vancouver.

National R-S Valve Engineering Service



No. 579

No. 579. Direct action float valve with counterweight assembly.

From coast to coast in strategically located cities, there are thoroughly experienced R-S Engineers who have made numerous R-S Valve installations that have effected outstanding efficiency and economy.

Practically universal in application, the R-S Butterfly Valve offers *simplified* control and shut-off of volume and pressure for any material that flows or is forced through a pipe—adapted to manual, float or power operation under high or low pressure and temperature. 15 to 900 psi.

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plained on the basis of elasticity for a given plasticity or film strength.

Simple Constant Reflux Take-Off for Distillation Systems. J. C. SNYDER AND W. STEUBER. *Ind. & Eng. Chem., Anal. Ed.* **16** (1944) p. 454.

In laboratory fractional distillation it is frequently necessary to control the reflux ratio so that it remains constant regardless of variations in the distillation rate. Methods for accomplishing this, as described in the literature, are reviewed by the authors. All of these devices require a degree of skill too great for fabrication by an amateur glass blower. The device described by the author is simple, inexpensive, has no moving parts, is characterized by low holdup, and is adaptable to distillation at other than atmospheric pressure.

Analytical Determination of Aromatic Hydrocarbons by Adsorption. B. J. MAIR AND A. F. FORZIATI. *J. Res. Natl. Bur. Stand.* **32** (1944) pp. 151-64 (Res. Paper No. 1582).

The authors describe a simple method for determining aromatic hydrocarbons in a solution such as gasoline. Filtration through a column of silica gel gives a filtrate free of aromatics. The concentration of aromatic in an unknown is determined by means of a calibration curve that shows the volume of filtrate produced through use of the standard adsorbent from solutions of various concentrations of the aromatic. Experimental data are given for several concentrations of aromatics in paraffins or naphthenes and for three concentrations of a solution of aromatic, paraffin, and olefin. A general procedure is outlined for determining the aromatic hydrocarbons in a straight-run gasoline and in a gasoline containing olefin.

Infrared Analysis of Butadiene. L. J. BRADY. *Ind. & Eng. Chem., Anal. Ed.* **16** (1944) pp. 422-4.

The author describes the infrared analysis of refined butadiene containing varying amounts of impurities such as butene-1, butene-2, traces of isobutylene and acetylenes, and small amounts of saturated hydrocarbons, the latter usually amounting to less than 5 percent of the total impurities present. The infrared absorption spectrum of an organic molecule is unique, and with few exceptions admixture with other compounds dose not affect this property. As a result, the concentration of any component in a solution can be determined by infrared analysis, provided it has at least one absorption band at a wave length where the other components are relatively transparent. Refined butadiene can easily be determined from the transmission of the sample at 6.9 microns. The apparatus and procedure are described in some detail and typical data are given in tabular form. Comparison is made with the results by the maleic anhydried methods. The gravimetric maleic anhydride procedure requires from 5 to 6 hours as compared to the 10 minutes needed to make duplicate infrared determinations. Because of rapidity and greater precision the infrared

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Laboratory Continuous Countercurrent Liquid-Liquid Extractor. J. J. KOLFENBACH, E. R. KOOI, E. I. FULMER, AND L. A. UNDERKOFLER. *Ind. & Eng. Chem., Anal. Ed.* **16** (1944) pp. 473-4.

The inefficiency of the ordinary types of laboratory extraction apparatus makes the recovery of solutes from solutions by extraction with immiscible solvents a time-consuming operation. A new type of laboratory countercurrent extractor has been designed and used extensively at the Iowa State College laboratory for the recovery of 2,3-butylene glycol and acetylmethylcarbinol from fermentation mashes and mash concentrates by extraction with diethyl ether. The unit has been found more efficient than any other type of extractor tested. It is described in some detail by the authors. The results of typical runs are presented in graphical form. The authors state that the apparatus can be used for extracting various liquids with different immiscible solvents. Modifications could easily be made to enable the use of solvents of greater density than the liquid to be extracted.

"Toluene Dilution Points" in Testing Lubricating Oils. N. W. GILLAM. *Australian Chem. Inst. J. & Proc.* **11** (1944) pp. 67-71.

The addition of toluene to a hydrocarbon blend lowers the aniline point of the solution to an extent proportional to the weight percentage of toluene added. Aniline-point lowerings for additions of toluene up to 50 percent by weight were found to be the same for all blends of volatile hydrocarbons and heavy lubricating oils. Beyond the 50 percent addition of toluene the depression curves diverged and the more volatile hydrocarbons showed greater lowerings of the aniline point. A "toluene dilution point" test is proposed for determining the aniline point of lubricating oils, particularly refined oils giving normal aniline points in the range 110-130°. For a wide range of products the addition of 50 percent of toluene was found to depress the aniline points uniformly 51 ± 1°. Extrapolation of the toluene depression curves indicate that the aniline point of the toluene is in the region —90° to —100° C.

X-Ray Studies of Chain Polymers. I. FANKUCHEN AND H. MARK. *J. Applied Phys.* **15** (1944) pp. 364-70.

The larger periodic or quasi-periodic constants can be determined by small-angle scattering of high polymers. Measurements must be made to 5 or 6 seconds for particles a few hundred A. in diameter and evacuated cameras must be used in order to eliminate scattering by air at a distance of 1 meter. Formulas are included for equatorial and meridianal intensities as functions of particle length and radius. In order to obtain micro-x-ray diagrams of small areas within a single filament a procedure employing glass capillaries 0.01 to 0.05 mm. in diameter as pinholes and single fibers or monofils as objects is used. The distance between the sample and the film is 5 to 15 mm. and an exposure time of several hours is required. Details are

A view of one of many plants designed and constructed by Petroleum Engineering, Inc., in the past 15 years of continuous service to the industry. *Petroleum Engineering, Inc., Offices: Tulsa and Houston.*

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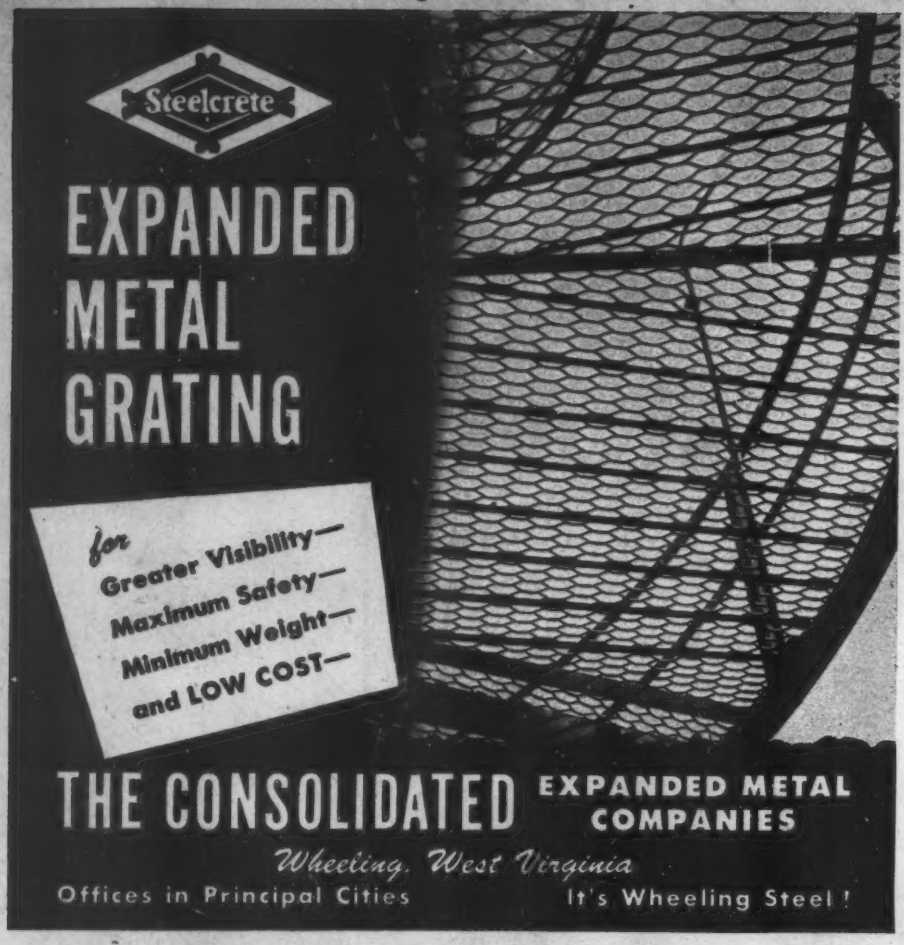

given of such an analysis as applied to the drawing of a nylon monofil.

Precision Viscometry. L. A. STEINER. *Chem. Age* (London) **50** (1944) pp. 385-8.

The importance of accuracy in viscometry has been emphasized by increased use of viscosity data for analytical purposes. Variation in calibration constant of viscometers with efflux time and the erratic behavior of capillary viscometers are considered. The author recommends that instruments be tested at several velocities when half finished and only those shown to be free of erratic behavior and variation of the calibration constant be completed. The use of electronic controls in connection with timers and constant-temperature baths is recommended. Advantages of the Steiner rolling ball viscometer are given.

Sampling and Analysis of Anhydrous Hydrogen Fluoride. C. F. SWINEHART AND H. F. FLISIK. *Ind. & Eng. Chem., Anal. Ed.* **16** (1944) pp. 419-22.

The production and use of anhydrous hydrogen fluoride in tank car quantities have required the development of an accurate procedure for its sampling and analysis. Hydrogen fluoride boils at 19.4° C. and on account of its volatility the serious danger of burns, and the tendency of impurities to segregate, a correct and safe sampling procedure is essential. Strict adherence to the procedure described by the authors is stated to yield excellent results. The apparatus required for a sampling, and the method of procedure, are described in some detail. The analytical procedure for determining sulfur dioxide, total acidity, sulfuric acid and fluosilicic acid is described. Typical results are presented covering duplicate analyses of each different tank car of anhydrous hydrogen fluoride.

Electron Presence Key to Corrosion?

Missing electrons may be the cue to the most important discovery yet made in combating corrosion.

From the research laboratory of General Electric Company comes the news that the stainlessness of stainless steel is not due to the presence of a surface oxide, as was formerly believed, but rather to electron vacancies in the atoms of the alloy.

Further experimentation disclosed that two other corrosion-resistant alloys, monel and hastelloy, owe their properties to the same condition. Hence it is believed that the absence of electrons may be the crux to eliminating corrosion. Knowing how it is prevented in some alloys will undoubtedly lead to more effective ways of overcoming it in others.

An atom is described as a nucleus around which revolve, in orbits or shells, from one to 92 electrons. In most metals all available space in the orbit is filled with electrons; but in a few, nickel, for example, the orbit will hold 10 electrons, but there are only eight present. For that reason nickel is corrosion-resisting. In alloying metals to use in corrosive conditions, the trick is to keep vacant some electron spaces, the more the better, according to these research engineers.

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2 Gasketed seals eliminate ground joints, and all maintenance troubles common to ground joint construction.

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4 Seals may be made or broken with a small standard wrench, — from the front — permitting close side by side installation in minimum space.

5 This new flanged construction permits interior of fintube to be inspected and cleaned without disturbing shell side seal.

6 Sturdy rugged design, employing forged steel flanges with stud bolting. All joints have been tested to several times normal operating pressures.

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NEW EQUIPMENT FOR THE MODERN PLANT

Power Pump

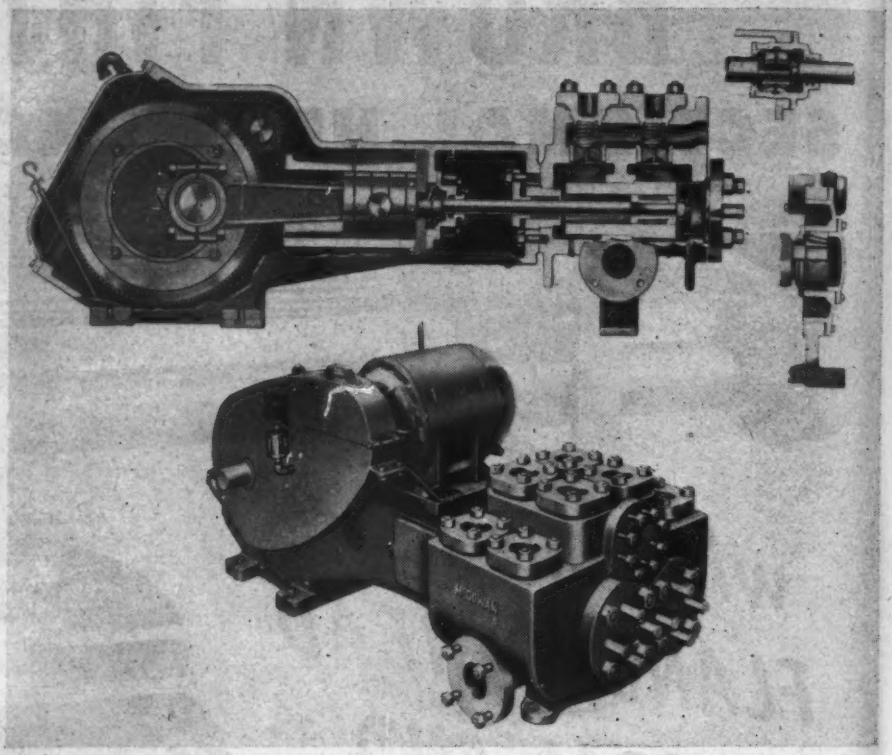
McGOWAN PUMP DIVISION

McGowan Pump Division of The Leyman Manufacturing Corporation, 44 Central Avenue, Cincinnati 2, Ohio, announces recent development of heavy-duty power pump, designed and engineered for dependable oil service.

The power frame is heavily-ribbed iron casting; the liquid end is made from very fine grained, controlled cast iron. Gears are continuous-tooth herring bone, and pinion is forged integral with the shaft, which extends to both sides for connection to driver. Pinion shaft floats on double row Timken roller bearings while the crank shaft also turns in Timken roller bearings. Crank bearings are adjustable by means of shims, and this cap does not support the weight of the bearings, the crankshaft and gear, as these are supported in a separate housing, purposely made larger for easy insertion of these moving parts. Consequently this pump is easily dismantled.

The liquid piston rod can be removed from the back of the crosshead by removing piston-rod cover and stuffing box in power frame.

The liquid end is a duplex side-pot type with a suction on either side. The valve areas are ample and pot caps are sealed with metal-covered gaskets, the same construction as used in cylinder heats. Liners are removable. Liquid ends of these models are available in commercial alloys depending upon requirements.



McGowan Power Pump

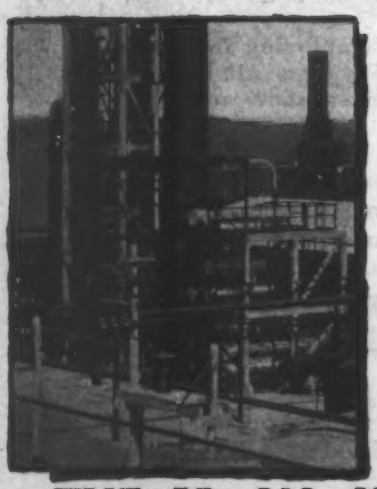
Insulate and Rust-Inhibit

AT THE SAME TIME WITH

THERMOSTIC No. 2

KELLOGG

Shipped in the form of dry cement Thermostic No. 2 mixes readily with water to form a smooth working; light weight and economical rust inhibited insulation for monolithic construction on stills, tanks, heat exchangers, towers, furnace walls, etc.



Users find this rust inhibited light weight insulation has a greater coverage capacity than average insulation and is unusually adhesive to hot or cold surfaces.

Thermostic No. 2 will not deteriorate and can be reclaimed for use again if temperatures have been maintained below 1200°F.

A test will prove its money-saving value to you.

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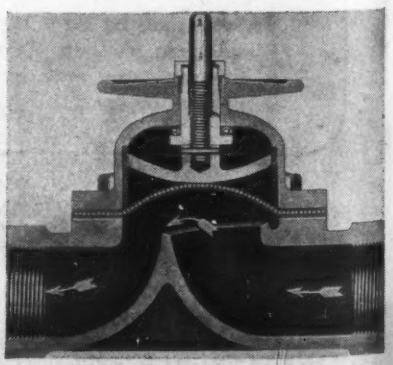
Diaphragm Valve

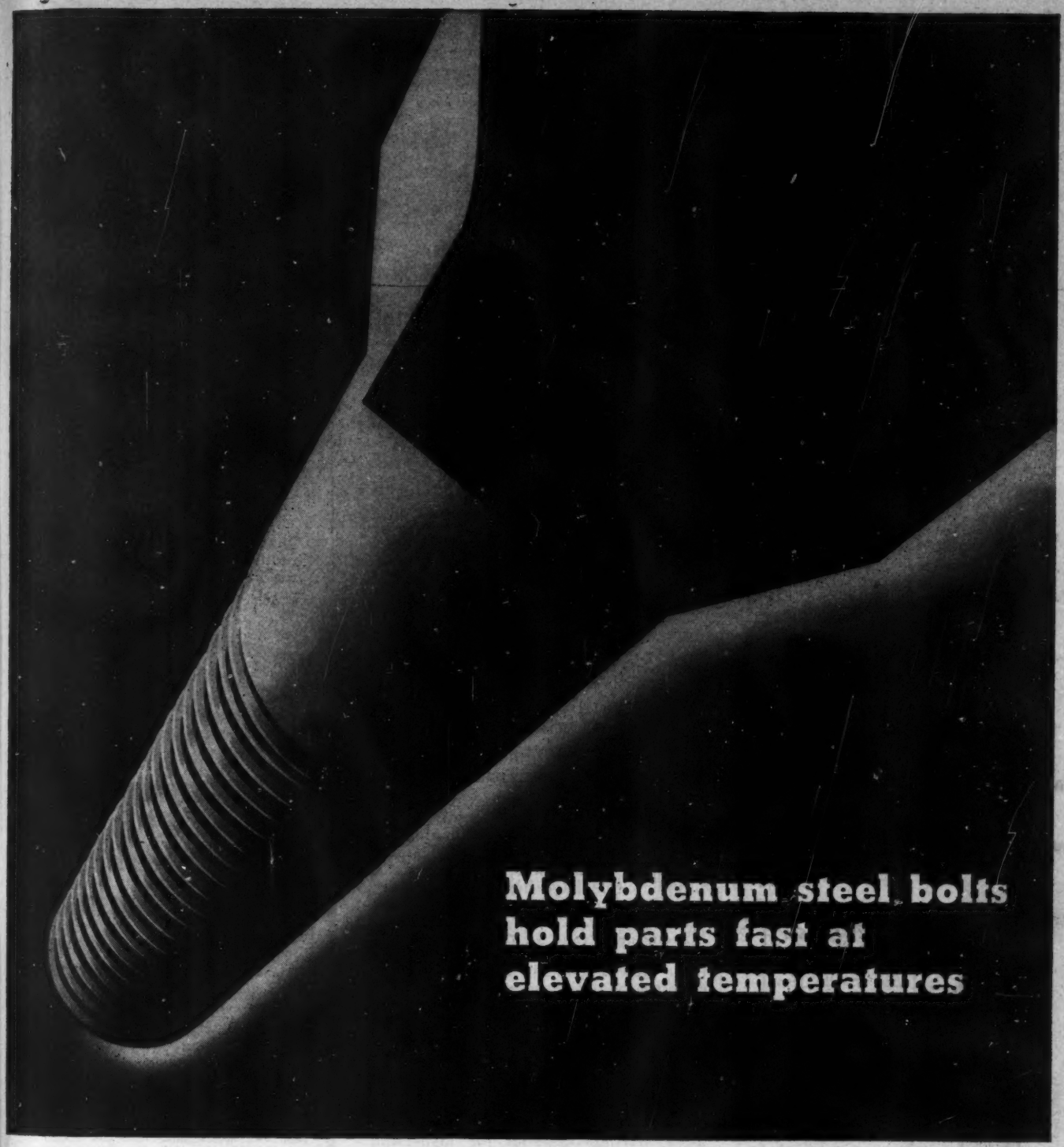
McALEAR MANUFACTURING COMPANY

McAlear Manufacturing Company, 1901 Southwestern Avenue, Chicago 8, has announced a diaphragm valve in which closure is effected through compression of a composition diaphragm against a metallic weir by pressure against the seal by a metal seat actuated by a screw and handwheel.

The valve is said to give positive shut-off, even though solid particles may be trapped on the face of the seating area. The closure seal, held tightly between seating area and compression disk, is not subject to pressure of the liquid being retained, the only stress being tangential to the face of the material as it is brought into place between fixed



McAlear Diaphragm Valve



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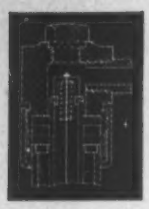
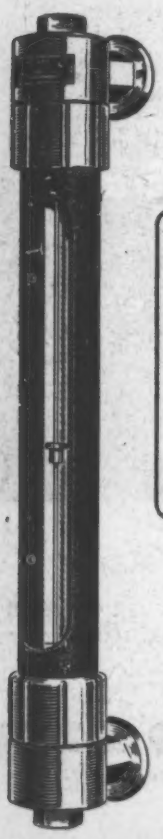
SOMETHING NEW IN *Rotameter* DESIGN



IN THE SERIES-100 ROTAMETERS, the guide rod is anchored to and centered in the metering tube by means of precision-made discs which fit snugly into the ends of the tube. This makes certain that the metering float is always in the exact center of the tapered metering tube throughout the entire length of the tube.

In older constructions, the guide rod was anchored to the end fittings by means of discs which were sealed in the drain plug cavities. In such Rotameters, the packing in the stuffing box becomes set after use, requiring tightening of the stuffing boxes. This, however, will draw the end fittings together, decreasing the tension in the guide rod so that the float no longer moves in the exact center of the tube. In the Series-100 Rotameters, adjusting the stuffing box in no way affects the guide rod tension.



PRECISION BORE
Interchangeable Tubing
All Series-100 Rotameters are supplied with precision bore interchangeable tubes of heavy wall Pyrex borosilicate glass. Tubes are formed on mandrels, annealed, polariscope inspected and check gaged by precision ball test. Tube is white-backed for maximum ease in reading.

Write for a copy of Publication R-100

COCHRANE CORPORATION
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PHILADELPHIA 32, PA.

COCHRANE—ROTAMETERS INC—
ROTAMETERS

and moving sections of the mechanism.

The diaphragm valve is so designed as to be installed at any intermediate angle, the seating area being self-flushing in any position. Since the diaphragm at all times forms a continuous seal between fluid-carrying and threaded sections of the valve, no stuffing box is required, and no special provision to prevent polution of liquid by valve lubricant is required.

Electronic Recorders

THE BROWN INSTRUMENT COMPANY

Release of an electronic circular chart electric controller for manufacture of either war or civiilan goods is announced by The Brown Instrument Company, Philadelphia, precision industrial instrument divison of Minneapolis-Honeywell Regulator Company. This is one of the first of its several electronic instruments to be released in quantities and with no rationing system planned.

The electronic recorder of the type released is being used in, and is of special interest to, the metallurgical and chemical industries. The release stipulations specify eight weeks for delivery of two models. Each model will have several new features, including a control point index which is in red and of the same general shape as the black temperature pointer.

In making known the release of the electric contact circular chart electronic potentiometer, the company also stated that other electric control models will be announced as soon as they are available.

Aliphatic Derivatives

THE CONNECTICUT HARD RUBBER COMPANY

New aliphatic compounds consisting of the even-numbered normal hydrocarbons from C_8 through C_{18} and the corresponding olefins, alcohols, ethers, mercaptans, thioethers, disulfides, and sulfonic acids have been developed by the Chemical Division of The Connecticut Hard Rubber Company, New Haven, as a result of research work in the synthetic rubber field. Most of these new chemicals are available in commercial quantities and are supplied in various grades from technical to "fine chemical."

The saturated n-alkanes are suggested for use as organic intermediates, laboratory solvents, and as standard hydrocarbons. The olefins, with the double bond at the first carbon, are interesting in organic synthesis, particularly as a starting material for dispersing agents, resins, oil additives, pharmaceuticals, and insecticides. Certain branch-chain olefins, isomeric with the n-compounds of this series are available for laboratory research. The alcohols are also suggested as intermediates for chemical synthesis and for use in cosmetic preparations.

The aliphatic ethers are an interesting series which can be used as plasticizers, impregnating agents, solvents and heat-transfer liquids.

The high-purity aliphatic mercaptans present possibilities as polymerization conditioners, intermediates for synthesis, corrosion inhibitors, oil additives, insecticides, flotation agents, and alarm odorants.

The thioethers and the disulfides are suggested for use as plasticizers, stabilizers, insecticides, oil additives, and flotation agents. The aliphatic sulfonic

ESPECIALLY RECOMMENDED FOR USE IN THE
COPPER SWEETENING PROCESS

Nichols
TRIANGLE BRAND
COPPER SULPHATE

is preferred by leading refineries because of its high copper content, dependable uniformity and exceptional purity and freedom from foreign and inert matter.

99% + PURE

Quotations on request, on any quantity required. Shipments can be made from our nearest plant.

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40 WALL STREET, NEW YORK
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PLIBRICO
Jointless FIREBRICK

The Answer to Your Refractory Problems!

FOR boilers and stills—for patching and repairs—for entire walls and complete relining—Plibrico Jointless Firebrick is the dollar-saving, trouble-saving refractory that refineries everywhere are adopting.

Plibrico forms a solid, monolithic lining that eliminates the weak joints of laid-up fire brick construction. Flexo-Anchors prevent bulging. No special shapes are required; Plibrico comes in moist, plastic form and can be readily moulded to any shape. Your own maintenance men can install it or we furnish complete installation service.

For extreme conditions, there is the Plibrico sectionally-supported air-cooled wall. And the Plibrico suspended arch for boiler arches and still roofs. Both are erected without special tile or heavy castings.

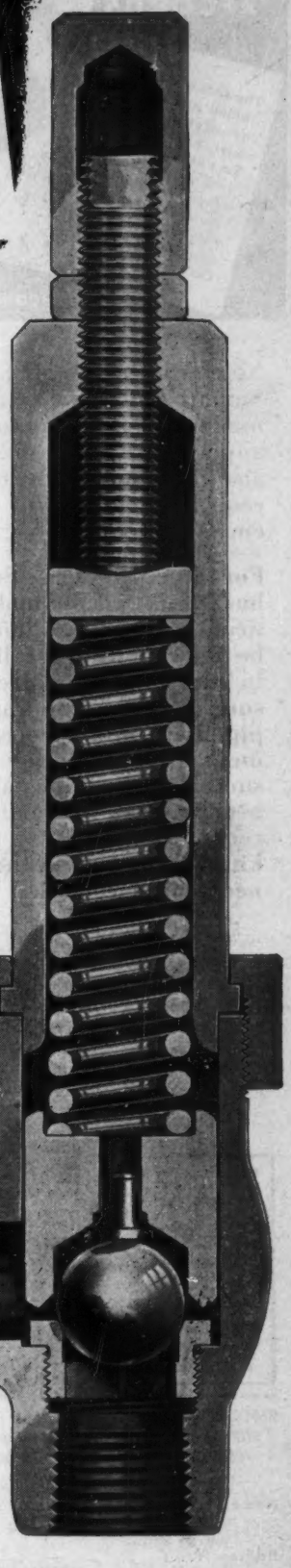
These catalogs cover your requirements.

Here is the complete story of Plibrico linings, arches, air cooling, etc. Ask for your Plibrico catalog. Specify whether operating H.R.T. or water tube boilers.

PLIBRICO JOINTLESS FIREBRICK CO.
1803 Kingsbury St., Chicago, Illinois

NUMBER FOUR OF A SERIES ON VALVE SELECTION

Protect equipment against abnormal pressure increases *with* Edward RELIEF VALVES



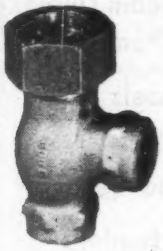
WHETHER for power, marine, chemical process, petroleum, refining, hydraulic or general industrial services, the most important consideration in selecting relief valves is *absolute dependability*.

Edward relief valves protect expensive equipment against sudden and unusual pressure increases in all kinds of services. Functional design, with only a few parts all built to extraordinarily high precision standards, and production-run quantities make Edward relief valves surprisingly low in initial cost and exceptionally economical over the long pull.

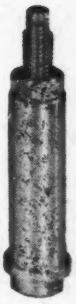
Since every valve is factory set for the required relieving pressure, inquiries should include information concerning service, frequency of operation, and relieving pressure.

Regularly available in ¼ in. to 2 in. sizes inclusive.

Look for These IMPORTANT POINTS



BODY
Drop forged heat treated steel. Distribution of metal around body flow areas equalized so that in heating and cooling there is negligible distortion.



BONNET
Rolled carbon steel, with body and locknut joints carefully ground for tight fit.

BEARING PLUG
Hardened stainless steel. Point contact always permits disk to reseat promptly and tightly.

BALL DISK
Hardened corrosion resistant stainless steel, accurately ground for tight seating.

SPRING
Fine carbon or stainless steel spring, adequate length for full area when discharging. Design of adjusting mechanism makes possible close pressure regulation.

SEAT
Renewable EValloy stainless steel, with sturdy shoulder and full threads engaging body.

FIG. 141

Is Edward BETTER VALVES *Catalog 102 in your files?*
If not, write for your copy today.

THE EDWARD VALVE & MFG. CO., INC. • EAST CHICAGO, INDIANA

EDWARD *Steel* VALVES

SMOOTH-ON
REPAIR
RECORDS
CRACKED BALL MILL
The ends of the crack were drilled and plugged and its edges beveled slightly with a sharp scraper. Smooth-On No. 1 was then applied under a reinforcing patch-plate and into the crack. The mill was again ready for use as soon as the Smooth-On hardened
FOLLOW THIS SERIES OF SMOOTH-ON SAVINGS

Note that this repair . . . like all Smooth-On repairs . . . was made without dismounting the apparatus or use of heat. Note also that none of the operations required special skill or experience.

For over 45 years, Smooth-On has been used for making practical, speedy, economical and lasting repairs . . . sealing cracks in pump, engine, valve and pressure castings, stopping leaks in pipelines and process equipment. Its outstanding record of successful routine and emergency repairs has made this iron cement a necessity in the repair kit of tens of thousands of engineers and mechanics.

Buy SMOOTH-ON in 7-oz., 1-lb., or larger containers from your supply house, or if necessary, from us. For your protection, insist on SMOOTH-ON, used by engineers and repair men since 1895.

FREE

REPAIR HANDBOOK SHOWS HOW

40 pages, 170 diagrams, and simple concise instructions for practical repairs to plant equipment, pipe lines and structures. A necessity in every plant. Your copy sent FREE if you fill in and return the coupon.

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Please send SMOOTH-ON HANDBOOK

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Address.....

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9-44

Do it with **SMOOTH-ON**
The Iron Repair Cement of 1000 Uses

acids, available only in experimental quantities, are of interest as hydrogen soaps, and the salts as stabilizers, dispersing agents, wetting agents, and oil additives. The corresponding sulphones are available in limited amounts for experimental work.

Trichlorcumene

HOOKER ELECTROCHEMICAL COMPANY

Trichlorcumene (isopropyl trichlorbenzene) $(CH_3)_2$—CH—$C_6H_3Cl_3$ is being produced in pilot-plant quantities by Hooker Electrochemical Company, Niagara Falls, New York.

Trichlorcumene is a colorless liquid with a mild aromatic odor. It is a mixture of Trichlorcumene isomers. It is insoluble in water and soluble in alcohol, ether, and most common solvents. It is highly stable, being resistant to oxidation and hydrolysis.

Trichlorcumene has been found to be compatible with the following types of plastics. The nature of the resultant material is indicated as soft (s), rubbery (r), tough (t), and brittle (b): modified phenolic resin (s), benzyl cellulose (t) (b), chlorinated piccolyte (s), phenol formaldehyde (s), ester gum (s), resin (s), natural asphalt (s), methacrylate interpolymer (t) (r), poly terpene resin (s), piccoumaron (s), poly vinyl chloride (r), polystyrene (r), and chlorinated rubber (r).

Suggested uses: hydraulic fluid, transformer, and dielectric fluids, anti-freeze additive for hydraulic, dielectric and heat-transfer fluids; solvent for fats, oils, waxes, coal-tar dyes, asphalts; solvent, diluent, and plasticizer for protective coating and insulating compositions; extractant for phenols, etc., from liquids such as waste waters; ingredient of insecticidal compositions, paint and varnish removers, paints, solvents and plastic compositions.

Physical data:

Molecular weight (pure trichlorcumene)	223.5
Freezing range, °C	—30 to —45
Boiling range, °C	245 to 265
Refractive index, n20/D	1.535 to 1.560
Specific gravity 15.5°/15.5°C	1.26 to 1.32

Additional physical data are available in the Hooker Preliminary Technical Data Sheet No. 347.

Plastic Tape

IRVINGTON VARNISH & INSULATOR COMPANY

Irvington Varnish & Insulator Company, Irvington 11, New Jersey, has developed a many-purpose plastic tape said to have widely divergent applications. It is used for insulating wires, cables and electrical equipment; for splicing cables; and for protecting wiring, piping and equipment exposed to caustic or corrosive fumes, oil, grease, acids, alkalis or moisture.

The tape is manufactured from vinylite resin. It is heat-sealing, flame resistant, and high in dielectric and mechanical strength.

Pressure Recorder

VULCO PRODUCTS COMPANY

Vulco Products Company, 409 West 36th Street, New York 18, has perfected a device for recording water pressure in pipe line, hydrants, faucets and pumpers, or wherever proper water pressure is a vital factor.

With the help of the device, the Dyna-Stat Test Pipe, any ratio between static and dynamic pressures not within an acceptable range can be immediately detected.

IF YOU'RE IN A HURRY....
CALL US FOR
REFINERY EQUIPMENT

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and
GUARANTEED

Valves and Fittings
Centrifugal—Steam Duplex and Simplex Pumps
Towers and Vessels
Storage Tanks—Horizontal and Vertical
Pipe—Tubes—Headers
Compressors
Instruments
Complete Refining Units—Cracking and Topping

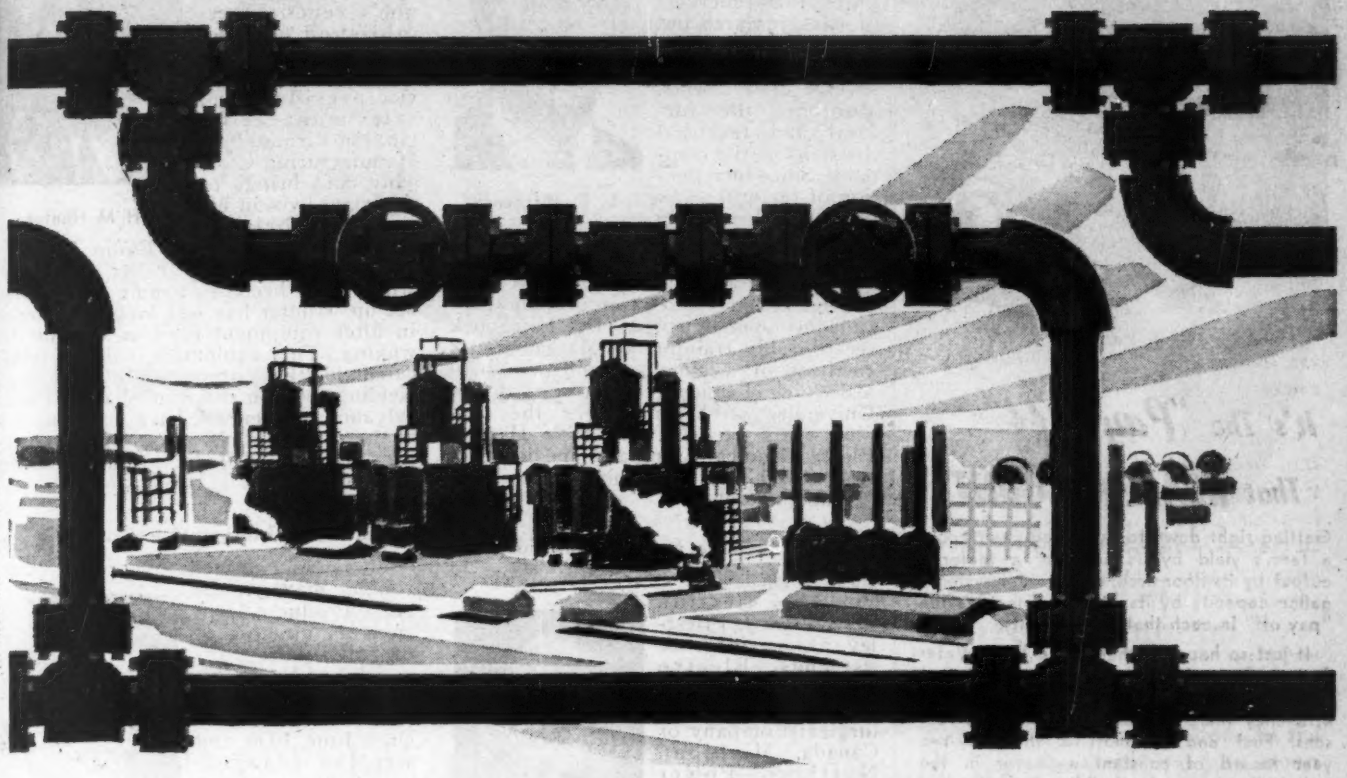
Refinery Equipment, Inc.

UNION AVE. AT 21st STREET
TULSA, OKLAHOMA

KARBATE
Trade Mark

PIPES, TUBES, FITTINGS

Withstand Virtually All Corrosive Chemicals



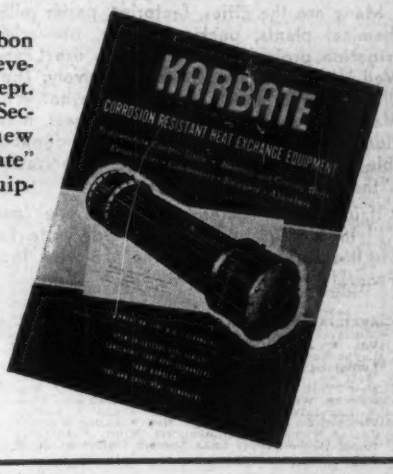
Can Be Assembled to Any Plan

PIPE, TUBES, FITTINGS, made of "National" carbon and graphite, or of "Karbate" materials (carbon or graphite made impervious to fluid seepage under pressure) are available in standard sizes for the chemical and process industries wherever corrosion problems exist.

These products, plus "Karbate" centrifugal pumps, Globe and Saunders valves, and heat exchangers, are fabricated into complete conveying and heat-transfer systems of practically any design.

This is because only "Karbate" materials have all these properties: High resistance to the action of most acids . . . notably hydrofluoric acid . . . and of alkalies and other corrosive chemicals; high mechanical strength, light weight, resistance to thermal shock, good machineability, and thermal conductivity exceeding that of many metals.

Write National Carbon Company, Inc., Cleveland 1, Ohio, Dept. **30-I,** for Catalog Section M-8802—a new bulletin on "Karbate" Heat Exchange Equipment.



★ BUY UNITED STATES WAR BONDS ★

NATIONAL CARBON COMPANY, INC.
Unit of Union Carbide and Carbon Corporation
UCC
General Offices: 30 East 42nd Street, New York 17, N. Y.
Division Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

The words "National" and "Karbate" are registered trade-marks of National Carbon Company, Inc.

It's The "Pay Off" That REALLY COUNTS

Getting right down to facts, you can't count a farm's yield by its acreage; a factory's output by its floor area, nor a water system's gallon capacity by its well diameter. It's the "pay off" in each that really counts.

It just so happens that Layne Well Water Systems have the very best "pay off" that engineering skill has yet achieved. For such efficiency there are many good sound reasons. First and foremost is the sixty-two year record of constant endeavor in the well-drilling and pump building field. Second is the meticulous care with which each system is built and installed, and third is Layne's unbroken policy of making no compromise with quality.

Many are the cities, factories, paper mills, chemical plants, packing houses, breweries, irrigation projects and mines who use Layne Well Water Systems almost exclusively. They all know that back of every Layne Well Water System there stands the largest, most widely experienced and constantly dependable ground water developing organization in the world.

If in a Well Water System it is the "pay off" in which you are interested, write for late literature. Address Layne & Bowler, Inc., General Offices, Memphis 8, Tennessee.

AFFILIATED COMPANIES: Layne-Arkansas Co., Stuttgart, Ark. ★ Layne-Atlantic Co., Norfolk, Va. ★ Layne-Central Co., Memphis, Tenn. ★ Layne-Northern Co., Mishawaka, Ind. ★ Layne-Louisiana Co., Lake Charles, La. ★ Louisiana Well Co., Monroe, La. ★ Layne-New York Co., New York City ★ Layne-Northwest Co., Milwaukee, Wis. ★ Layne-Ohio Co., Columbus, Ohio ★ Layne-Texas Co., Houston, Texas ★ Layne-Western Co., Kansas City, Mo. ★ Layne-Western Co. of Minnesota, Minneapolis, Minn. ★ International Water Supply Ltd., London, Ontario, Canada

LAYNE

WELL WATER SYSTEMS

DEEP WELL PUMPS

BUILDERS OF WELL WATER SYSTEMS FOR INDUSTRIES AND MUNICIPALITIES

☆ BUSINESS NOTES ☆

The Quaker Oats Company, 1900 Board of Trade Building, Chicago 4, has organized a chemicals department, with Dr. Lauren B. Hitchcock as manager. This department will integrate the functions of sales, research and production heretofore carried out by several departments, absorbing the furfural and technical divisions of the company. Since introduction of furfural as an industrial chemical in 1922, several derivatives, including furfurly alcohol, tetrahydrofurfuryl alcohol and hydrofuramide, have been placed on the market, and others are in laboratory and development stages. Dr. Hitchcock received his training at Massachusetts Institute of Technology and was professor of chemical engineering at the University of Virginia. For the past nine years he has been with Hooker Electrochemical Company in both research and sales departments, lately as manager of sales.

L. B. Hitchcock

Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, announces election of William J. Priestley as president of its units, Electro Metallurgical Company, Electro Metallurgical Company of Canada, Michigan Northern Power Company, and Union Carbide Company of Canada. He succeeds the late Francis P. Gormely. Priestley was graduated from Lehigh University in 1908 as a metallurgical engineer, and entered the employ of Bethlehem Steel Corporation. He became superintendent of the armor-plate plant and was subsequently division superintendent in charge of all ordnance production for that company. During World War I, he entered government service and became the civilian head of the armor-plate and ordnance plant erected by the Navy. Later, he managed a steel plant making high-grade alloy steels for the automotive industry. In 1923 he became consulting metallurgist for Electro Metallurgical Company. He became vice president in charge of sales development in 1932. He was chief of the alloy steel division of the War Production Board during the period of organization for the expansion of alloy steel production in 1942.

W. J. Priestly

Girdler Corporation, Gas Processes Division, Louisville, Kentucky, has added Oliver E. Auer to its process engineering staff. Auer for the past two years has been chief of the materials conservation section of the War Department's engineering board at Fort Belvoir, Virginia, and formerly was with the East St. Louis, Illinois, refinery of Socony-Vacuum Oil Company.

General American Process Equipment, a Division of General American Transportation Corporation, announces that Henry M. Hunter recently has become associated with the organization's recently established filter design and sales unit. Hunter formerly was vice president and sales manager for Goslin-Birmingham Manufacturing Company, and brings to this new division his former associates, George D. Dickey and Philip B. Sadtler and their Conkey Filter Company, which now becomes a unit in the new set up. Hunter has had long experience in filter equipment used in solvent dewaxing. This equipment will be fabricated in the corporation's plate and welding division shops at Sharon, Pennsylvania. Hunter will have headquarters at the corporation's offices in the Graybar building, 420 Lexington Avenue, New York.

H. M. Hunter

American Locomotive Company announces appointment of Hugh Corrough, manager of Alco Products Division, as director of the division. Corrough has been with Alco Products Division of the company since June, 1936, and served in the capacities of chief mechanical engineer, assistant manager of engineering, manager of engineering, and manager of Alco Products Division. He is a graduate of Iowa State College and was connected with Empire Oil & Refining Company in various capacities from 1923 until 1934, when he became associated with Cities Service Oil Company as an executive.

Hugh Corrough

Pittsburgh Equitable Meter Company-Merco Nordstrom Valve Company, Pittsburgh, announced appointment July 1 of A. J. Kerr as general sales manager of the combined organizations. Kerr has been with the companies 20 years and was district manager at Tulsa until his promotion to headquarters. He is a graduate in mechanical

A. J. Kerr

C. K. Madison

LUCAS
SAFETY EXPANSION JOINTS

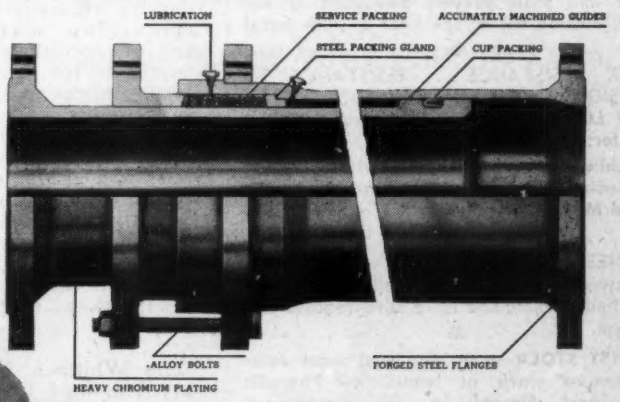
Safety, versatility, economy

Made of forged steel and precisely machined, Lucas Safety Expansion Joints have a record of perfect performance. The positive stop feature of these joints makes it impossible for them to part while in service. Each unit is shop tested.

Design flexibility makes it possible to custom-build Lucas Expansion Joints to meet the specific requirements of each job.
Maintenance costs are reduced to a minimum by repacking while in service.

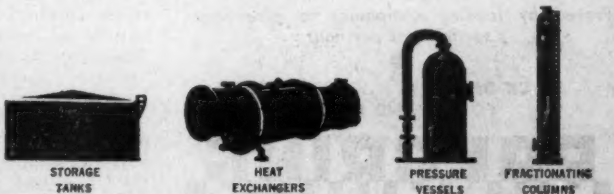
INQUIRIES SHOULD SPECIFY:

1. Type of Service (water, oil, gas or steam).
2. Working Pressure (psi) & Temperature (°F).
3. Length of Traverse desired.
4. Traverse (single or double).
5. Flanges (if special flange facing is required. Note: Flanges can be omitted and ends beveled for welding).
6. Anchor Feet if required. (If Anchor Feet are ordered specify vertical or horizontal installation).



Southwest Welding & Manufacturing Company

ALHAMBRA, CALIFORNIA



Complete Facilities for All Refining Fabrication

Plastics

BAKORINGS

Made of

LAMINATED PHENOLIC PLASTICS

As the plastic material of these rings is practically self-lubricating, temporary loss of lubricant will not affect the life of the piston rings or the liners.

Grit and scale become embedded in the plastic and do not scrape liner as with metal rings.

SHOCK RESISTANCE . . . RESISTANCE TO ABRASION AND WEAR . . . HIGH STRENGTH WITH LOW WEIGHT make Phenolic Plastics ideal for:

- Bushings
- Bearings
- Electric Insulators
- Wearing Rings in Centrifugal Pumps
- And Many Other Products

ENGINEERS familiar with these excellent properties of Laminated Phenolic Plastics are daily finding more and more advantageous uses for them.

LARGEST STOCK of Tubing and most comprehensive stock of Laminated Phenolic Rods and Sheets in the Southwest.

Proved by leading companies to give lower service cost per hour

QUICK DELIVERY . . . WRITE FOR FOLDER AND PRICES

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INCORPORATED
1020 HOUSTON, AVENUE
HOUSTON, TEXAS

M. D. Gilbert

W. S. Andrews

engineering from Carnegie Institute of Technology. M. D. Gilbert has been appointed district manager at Tulsa; C. K. Madison district manager at Houston, and W. S. Andrews district manager at Pittsburgh. Gilbert and Madison formerly served as service engineers in the Midwest, and Andrews, formerly service engineer at Pittsburgh, recently has traveled Ohio for the company, out of Cleveland.

J. O. Ross Engineering Corporation announces that S. W. Fletcher, for many years executive vice president of the corporation, has been elected president and will continue to make his headquarters at New York. A. E. Montgomery will continue as vice president of the company with headquarters at Chicago. Other officers include H. G. Rappolt and F. W. Partsch, vice presidents; J. A. Ronder, treasurer, and R. W. Grott, secretary.

S. W. Fletcher

D. D. Foster Company, equipment consultants, has been organized by D. D. Foster (A. H. Stroyd, associate), with offices at 412 Peoples Gas Building, Pittsburgh. The company will handle engineering and sales of specialized equipment for the oil, gas and chemical process industries in Pennsylvania, Ohio and West Virginia. Foster is a graduate of Carnegie Institute of Technology, and has been with Pittsburgh Equitable Meter Company-Merco Nordstrom Valve Company 15 years, recently as acting general sales manager.

D. D. Foster

The Whitlock Manufacturing Company, Hartford, Connecticut, announces appointment of Norman W. Stirling as manager of sales. Stirling graduated from Buchtel College in 1917 and was appointed to the United States Naval Academy, was transferred to the Navy Steam Engineering School at Stevens Institute, and after being commissioned spent some time at sea, later studying turbo-electric drive at the University of Pittsburgh. Resigning from the Navy in 1922, he and a brother operated a machine and boiler company until 1928, when he joined The M. W. Kellogg Company, with which he continued until his present connection. Stirling was

EAGLE BLANKET
Insulation
For Temperatures up to 1200° F.

Manufactured from gray mineral slag wool—water repellent—fire proof—will not deteriorate. Readily obtainable in any thickness for immediate shipment.

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Refineries—Pipe Lines
Gasoline Plants

our organization has specialized on purchase and disposal of refineries; pipe lines; gasoline plants for more than 30 years. Owners of properties have received successful results. We are NOT auctioneers or brokers.

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LET US FIGURE WITH YOU ON FABRICATING YOUR HIGH PRESSURE AND PROCESS PIPING.

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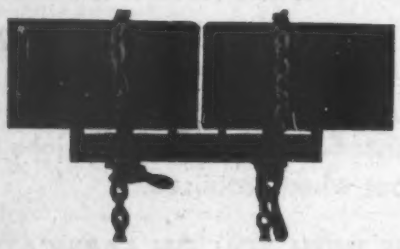

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Faster... Easier... Truer

WITH

JEWEL PIPE CLAMPS

They align pipe perfectly and hold it secure for tacking. On in a minute—off in ten seconds. Two sizes, ½ to 8 in. — 8 to 16 in. Rigid construction resists strain, heat, and abuse.

Other Jewel Clamps for Ells, long and short turn — for Flanges — for Headers. Also Pipe Marker, eliminates patterns for holes and saddles.

So simple — so easy to use — Jewel Tools are proving big time-savers in refinery piping fabrication and erection.

Write Today for Details and Prices.

JEWEL Manufacturing Company
1841 University Ave.
ST. PAUL 4, MINNESOTA

instrumental in organizing the heat transfer department of The M. W. Kellogg Company and was sales manager of that department, being in charge of Navy and Maritime contracts for the company during the past four years.

Haynes Stellite Company, a Unit of Union Carbide and Carbon Corporation, has elected E. E. LeVan, president, to succeed the late Francis P. Gormely. LeVan entered the employ of Haynes Stellite Company as a sales engineer in 1922, becoming chief engineer three years later. In 1927 he entered the sales department, and in 1929 became general sales manager. He was elected vice president in 1939, and in May, this year, was made vice president and general manager. He will continue to make his headquarters at Kokomo, Indiana.

E. E. LeVan

John Waldron Corporation, New Brunswick, New Jersey, announces election of B. R. Newcomb as the corporation's president. Formerly with Worthington Pump & Machinery Corporation, Newcomb more recently has been with American Optical Company. Election of S. N. Finney and F. W. Egan as vice presidents of John Waldron Corporation also was announced. Both have been associated with the organization for a number of years.

B. R. Newcomb

Wheelco Instrument Company, Chicago, announces that Charles L. Saunders, recently resigned as branch chief of the WPB office of civilian requirements, has been elected a vice president of the company. Saunders, an electrical engineering graduate of the University of Virginia, served The Brown Instrument Company as salesman and district manager at Birmingham, Houston, Pittsburgh and Chicago, and was elected resident vice president at Chicago for Minneapolis-Honeywell Regulation Company when The Brown Instrument Company was acquired in 1935.

Pittsburgh Equitable Meter Company has appointed H. D. Leisenring manager of its gasoline- and oil-meter division to succeed H. I. Beardsley who soon will retire after serving the com-

H. I. Beardsley

H. D. Leisenring

DESIGNERS • DRAFTSMEN
and
SQUAD LEADERS

For Process Piping on Oil Refineries; also Designers and Checkers on Pressure Vessels.

Applications solicited from men not now employed in essential work or those completing essential work who have Statements of Availability.

ARTHUR G. McKEE & COMPANY
2300 Chester Avenue
Cleveland, Ohio

ENGINEER WANTED

The Field Research Department of Magnolia Petroleum Company, located near Dallas, has an opening for a junior mechanical or chemical engineer. Work will consist of contacting research and development groups, ascertaining their apparatus and equipment needs and designing, procuring, following assembly and testing same. Job requires 4 to 5 years experience in chemical process work, some familiarity with design procedures, instrumentation, ability to sketch up ideas for drafting and to get along with technical and shop people. This is a job of future possibilities beyond "V" day. Applicants should enclose small photograph and must have statement of availability. Address: Box 555, c/o Petroleum Refiner, Houston, Texas.

WANTED—INSTRUMENT MEN

For new Aviation Gasoline Refinery consisting of Catalytic Cracking, Alkylation, and Isomerization units. Location, Middlewest. In reply give detailed outline of previous experience, education, draft status, and required earnings for 48-hour work week. Reply: Box 50, c/o Petroleum Refiner, Houston, Texas.

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KETTLES, AUTOCLAVES, DIGESTERS
BLENDERS, PEBBLE & BALL MILLS

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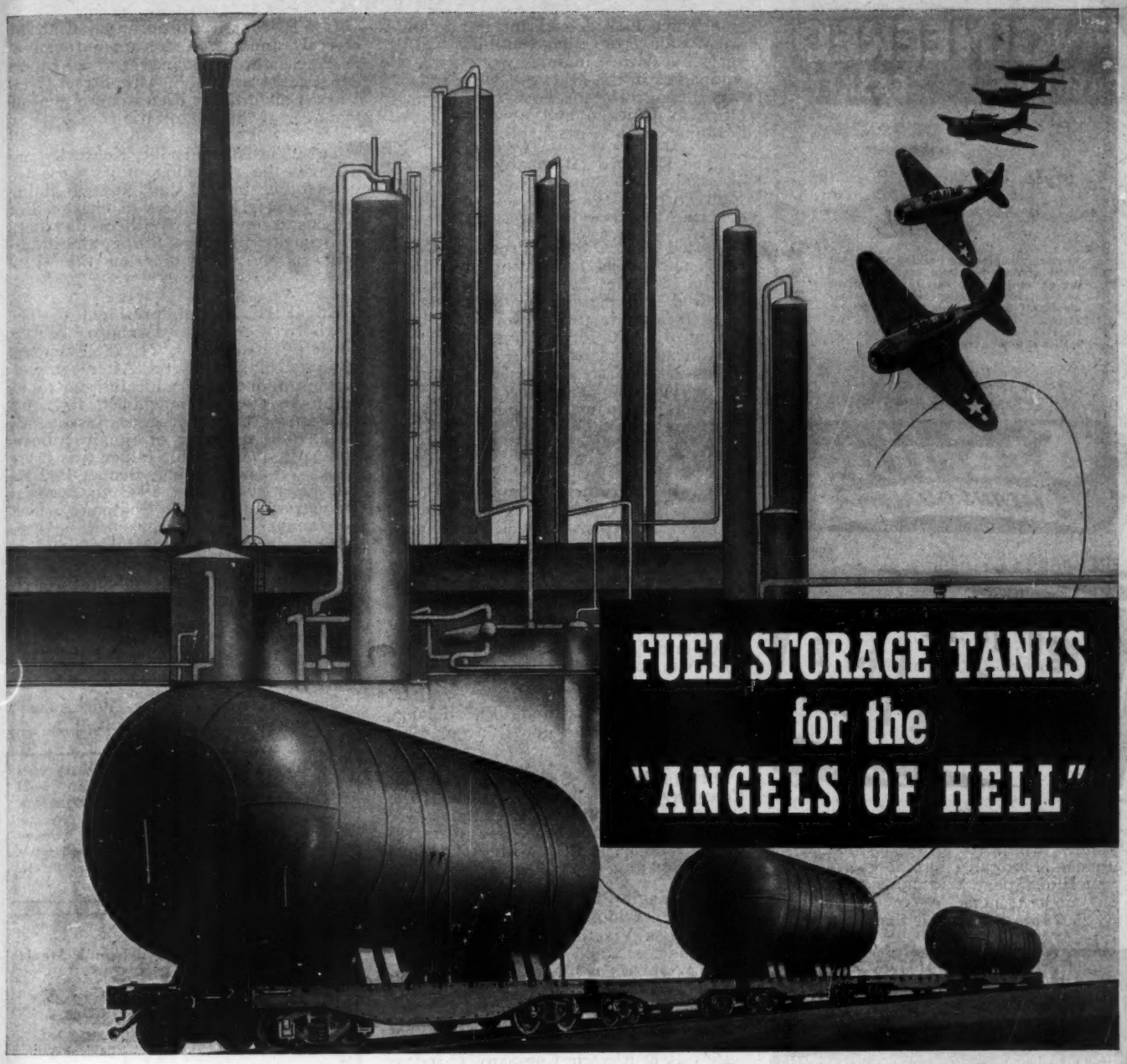

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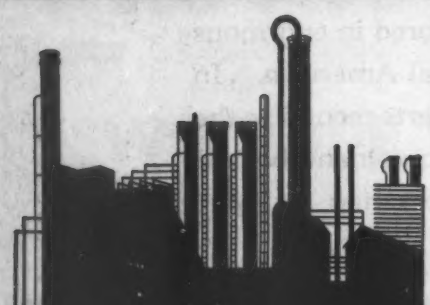

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pany since 1912. Leisenring is a graduate of Lafayette College, and has had 10 years experience in sales work with oil companies in the Midwest. He formerly was manager of the company's branch office at Chicago and now will make headquarters at Pittsburgh.

The Foxboro Company, Foxboro, Massachusetts, announces addition of Paul Torre to its staff of sales engineers covering the New England territory.

United States Steel Products Company, sheet-steel fabricating subsidiary of United States Steel Corporation, has acquired the manufacturing assets of Bennett Manufacturing Company, consisting of plants for making steel drums at Chicago and New Orleans. These plants will operate as Bennett Manufacturing Division of United States Steel Products Company. Stevens A. Bennett has been appointed a vice president of the latter company and will be in charge of the division.

Brown Instrument Company, Philadelphia, recently was given a second renewal of the Army-Navy E. An innovation, ceremonies of acceptance was left entirely in the hands of employes, no company nor government officials taking part.

Kerotest Manufacturing Company, Pittsburgh, has been awarded a fourth gold star to add to its Maritime M pennant.

Cochrane Corporation, Philadelphia, received renewal of its E award late in July.

Pennsylvania Salt Manufacturing Company, Philadelphia, has secured the services of Dr. William A. LaLande, Jr., as director of research. He formerly held a similar position with Attapulgus Clay Company.

The Eagle-Picher Sales Company, Cincinnati, Ohio, announces promotion of Douglas Via to industrial insulation sales manager, and appointment of Andrew L. Harris as manager of sales promotion. Via has been with the company nine years, and has been active in sales engineering since leaving the University of Virginia in 1922. He served Louisville Gas & Electric Company as industrial engineer, and prior to that was branch manager for York Ice Machinery Corporation. Harris comes to his new connection from the National Association of Manufacturers, where he was an executive in public relations work. Previous to that he was engaged in sales promotion work for United States Gypsum Company.

Jas. P. Marsh Corporation, Chicago, recently announced the appointment of R. S. Gaisford as manager of its export department at 155 E. 44th Street, New York. Gaisford has been eastern division manager of the organization.

Tube Turns, Louisville, Kentucky, announces the reopening of its Los Angeles office in the Van Nuys Building with James H. Withers in charge. For the last nine years Withers has been associated with valve, fitting, and industrial supply companies on the West Coast.

Edgar H. Bristol, president of The Foxboro Company, Foxboro, Massachusetts, died July 24 at Falmouth Heights, Massachusetts. After completing his high school education he found employment as a machinist, later becoming a tool-maker and subsequently production manager of the instrument company of which his father was president. With his brother, Bennet B. Bristol, he withdrew in 1908 to organize Industrial Instrument Company which, on January 1, 1914, became The Foxboro Company. Bristol maintained an active participation in the company's affairs, serving as its president throughout its history. More than 40 patents were recorded to his credit, some of them so basic in character as to establish new principles of instrument design and operation.

Sarco Company, New York, has a second star for its E pennant.

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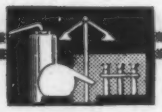

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